## EXTREME WEATHER EVENTS: THE COSTS OF NOT BEING PREPARED

#### **HEARING**

BEFORE THE

# COMMITTEE ON HOMELAND SECURITY AND GOVERNMENTAL AFFAIRS UNITED STATES SENATE ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

FEBRUARY 12, 2014

Available via the World Wide Web: http://www.fdsys.gov/

Printed for the use of the Committee on Homeland Security and Governmental Affairs



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#### EXTREME WEATHER EVENTS: THE COSTS OF NOT BEING PREPARED

#### WEDNESDAY, FEBRUARY 12, 2014

U.S. SENATE, COMMITTEE ON HOMELAND SECURITY AND GOVERNMENTAL AFFAIRS, Washington, DC.

The Committee met, pursuant to notice, at 10:03 a.m., in room SD-342, Dirksen Senate Office Building, Hon. Thomas R. Carper, Chairman of the Committee, presiding.
Present: Senators Carper, Begich, and Johnson.

#### OPENING STATEMENT OF CHAIRMAN CARPER

Chairman CARPER. Well, welcome one and all. Great to see our witnesses. Great to be here with Senator Johnson, and we will call this hearing to order. I appreciate the effort of all of you to get here today. I am glad we are having the hearing today and not tomorrow, because if we were having it tomorrow, we might not be having that hearing.

Today's hearing, as you know, is focused on the costs of not being prepared for extreme weather events and exploring the ways that our Federal Government can increase resiliency in our communities—and I would just underline this—and save money in the long haul. Deficits are coming down-they are still too muchfrom \$1.5 trillion, I think, 4 years ago, and this year we expect to be down to only \$550 billion. That is still way too much, and we have to continue to look in every nook and cranny and figure out how do we save more money, and that is the focus of today's hear-

But I will try to take about 5 minutes for my opening statement and yield to Senator Johnson. I am delighted that he is here. And then we will recognize our first panel of witnesses. Each witness will have about 5 minutes to offer your statement to our Committee. Following your statements, we are going to have a question-and-answer period. And then a second panel of witnesses will come forward, and we look forward to hearing from you as well.

Unfortunately, extreme weather appears to be the new norm. Events like Superstorm Sandy, which came to my shores and our shores in the Mid-Atlantic a year or so ago, recent wildfires in other parts of the country, dangerous tornados, and historic droughts may well be just the tip of the iceberg of what is to come.

And even today, the East Coast is preparing for yet another snow storm while the West Coast is experiencing a historic drought and increased fire danger with no end in sight. I have a friend who is

from Australia, and he tells me that they had the hottest weather in their history. So go figure. It is just sort of a crazy world that we live in right now.

For years, I have been working with a number of our colleagues to address the root causes and unfolding effects of what I believe is one of the biggest challenges of our generation, and that is, climate change

According to the U.S. Global Change Research Program, extreme weather events have increased in frequency over the past 50 years or so and are expected to become even more common, more intense, and more costly.

But let me just make a point and I will underline this, if I could: Today's hearing is not intended to hash out climate science. That is not what we are trying to do. Instead, it is about trying to find common ground.

As our country debates how to address our changing climate and the extreme weather I believe it is likely causing, our witnesses will deliver to us a clear message, and that is, put simply, the increase in frequency and intensity of those extreme weather events are costing our country a boatload of money—not just the cost that is measured in lives that are impacted but in economic and financial costs as well.

For example, the damage from a storm still fresh in many of our minds, Superstorm Sandy, which impacted, again, my home State of Delaware and many of our neighbors, is estimated to have cost our economy \$75 billion—think about that—\$75 billion in financial damages. And that is enough to run a number of departments of our Federal Government and have money left over. That is just one storm.

We are also hearing reports about the devastating effects of California's severe drought and how it is impacting the wildfire season in that State and across the West. Not only are wildfires growing in frequency and severity, but we are now seeing severe fires and wildfire conditions in winter and spring, well beyond the traditional wildfire season of summer and early fall. These fires are enormously expensive to fight and to recover from, and they pose serious threats to lives and property, damaging homes and businesses alike.

According to a 2013 report by insurance company Munich Re, the nearly 40 wildfires last year in the United States cost our economy over \$1 billion.

These economic damages can deliver a devastating blow to many local communities, to States, as well as to our own Federal Government.

The Federal Emergency Management Agency (FEMA) alone has obligated, I am told, over \$80 billion in Federal assistance for disasters declared in fiscal years (FY) 2004 through 2011.

However, the cost to the Federal Government is not just limited to disaster relief. As an insurer of both property and crops, the government faces additional significant fiscal exposure.

For example, since the creation of the National Flood Insurance Program (NFIP) in 1968, through December 2013 FEMA's debt from insurance payments to that program have totaled approximately \$24 billion. And even before Superstorm Sandy, the total debt from payments through the National Flood Insurance Program was almost \$18 billion.

The costs of these weather events keep going up at a time when we are trying to bring our government spending down. That is one of the reasons why, for the first time, the Government Accountability Office (GAO) last year listed climate change as one of the biggest fiscal risks facing our country in its high-risk list report.

Just to remind us all, every 2 years, at the beginning of every Congress, GAO gives us a high-risk list. Senator Johnson, you have heard me say this before. We use that as our to-do list on this Committee, to figure out other new ways or old ways to save money and get better results for less money, and we are thankful for that

to-do list.

But in response to this historic GAO announcement, House Oversight and Government Reform Committee Chairman Darrell Issa stated, and this is a quote from Darrell: "the Comptroller General has made it very clear that we have not prepared properly, that the Federal Government has a financial risk that we have not properly

mitigated, I think is a wake up call to all of us.'

I could not agree more. GAO's report is a call to action for both Congress and the Administration, warning us that our country must start thinking now about how to better prepare and adapt to a new climate reality. Today, our witness from GAO will further detail these financial risks to our communities and to our taxpayers and, hopefully, offer some commonsense solutions that my colleagues and I can work with the Administration to see implemented.

Fortunately, this Administration, along with a number of State and local governments, are starting to focus their efforts on preparing for the very real threats posed by extreme weather events and climate change.

Last fall, President Obama issued an Executive Order (EO) on Climate Preparedness that incentivizes investments in more robust roads and buildings that may be more expensive, but can hold up

during more intense storms.

I commend the President's approach and believe it is very timely as rebuilding efforts continue from Superstorm Sandy and other recent natural disasters.

I look forward to hearing more about the President's efforts and efforts by States like Delaware and a bunch of other States to do a better job protecting our communities and our taxpayer dollars from these challenges.

As we continue to debate how to reduce our deficits, I believe we cannot afford to ignore the impacts these weather events are hav-

ing on Federal spending.

A little extra planning—combined with prudent, targeted investments—can go a long way in saving both lives and taxpayers dollars. I believe this is a perfect example of that very wise maxim I used to hear from my grandmother all the time: An ounce of prevention is worth a pound of cure.

Thanks again to our witnesses for being here. We are eager to

hear your testimony.

With that, I am going to turn it over to our Acting Ranking Member, Senator Johnson from Wisconsin, for any thoughts, Ron, that you would like to offer. I am delighted that you are here. Thanks for coming.

#### OPENING STATEMENT OF SENATOR JOHNSON

Senator JOHNSON. Thank you, Mr. Chairman. Of course, I am mindful the reason I am sitting in this chair is because Dr. Coburn is not here, so he is in our thoughts and prayers.

Chairman CARPER. He sure is.

Senator JOHNSON. I want to thank you and I want to thank our

witnesses, and I am looking forward to the testimony.

When it comes to this issue, the questions I am going to be looking to have answered is, first and foremost, since I have been here and have been looking into this issue, we are really declaring Federal disaster declarations on a much more frequent basis. Now, is that because we really have a higher incidence of the types of disasters that require that, or are we just too quick to declare those disasters?

I am afraid that if we have an overreliance on the Federal Government's help, is that restraining the mitigation—the new word I am hearing is "resilience"—in terms of how we prepare? Are we being penny-wise and pound-foolish by not spending the money up front to mitigate? And, again, is the overreliance on Federal help when these disasters hit, everybody is expecting the Federal Government to come in and pay for things as opposed to actually miti-

gating these risks ahead of time?

And so from my standpoint, coming from the private sector, I certainly understand that a private insurance market provides very strong discipline in terms of mitigating risks, whether it is fire risk in a plant, basically insurers come in there and say, listen, if you put in sprinkler heads every 6 feet apart versus every 24 feet apart, you are going to be able to mitigate that risk, and you are going to be able to lower your insurance price. So I really have not experienced that private sector insurance market is a very good discipline to those risk mitigation efforts, and, those are the kind of questions I am asking in terms of how can we certainly utilize the Federal Government in the most efficient way, because, like you said, Mr. Chairman, we do not have the money to do all these things.

So, again, I look forward to the testimony.

Chairman CARPER. Senator Johnson, thanks so much.

We have been joined by a fellow from a little State, Alaska. [Laughter.]

A little State with a big population, and a couple of great Senators.

Senator BEGICH. Yes, there you go.

Chairman CARPER. Mark, would you like to say a word or two?

#### OPENING STATEMENT OF SENATOR BEGICH

Senator Begich. You bet. Small population, but a State with a big punch. But I would say in Homer, Alaska, I think last week we had green grass, so things are definitely changing.

First, Mr. Chairman, I would like to read a statement for the record, if that is OK, and I apologize I will not be able to stay. This

is a fairly important issue, especially when you talk about extreme weather events and how to prepare for them.

But first let me say, Mr. Chairman, I want to thank you and I appreciate you holding this hearing to examine what I consider the true costs of not being prepared for impacts of extreme weather. We are about to feel it. As I drove in today, I drove across salt, because they are waiting for snow to fall, to melt it. In Alaska, that would be unheard of. But that is the way it works.

Now, the weather conditions will also change, and I am sure we will have power outages and many other things. We understand very extreme conditions in Alaska. A normal winter day in Barrow or Fairbanks, we will get to below zero many times, and in some cases that would be extreme down in the lower 48 but not in Alaska.

Alaska truly is on the front lines in terms of changing climate. The effects of extreme weather and existing challenges facing our communities, including retreating sea ice, rapidly eroding shorelines, thawing permafrost, ocean acidification, are impacting our economy on many different levels. This reality puts many communities at risk throughout our State.

The U.S. Army Corps of Engineers (USACE) and the GAO have both released reports identifying Alaska villages imminently threatened by erosion. Many of these villages have experienced incredible extreme weather, 30-plus villages at risk of literally falling

into the ocean or disappearing totally.

Flooding wiped out a village in Alaska called Galena, totally. We had a whole village wiped out by flooding and no place to evacuate. The closest place was 270 miles away. It all had to be done by air in order to move these people out quickly, and now they are trying to rebuild in a very short time, and the winter set in, and it was also very difficult.

I know when people talk about climate change, they get nervous. Do they want to debate the science? I am telling you, climate change is occurring. My State is the example of it, of what the impacts are, and it is extreme. And we are seeing the impacts eco-

nomically and from all levels.

Our State has the longest coastline in the United States. It has incredible beauty but also has economic value. It also has enormous vulnerabilities in the sense of the impacts it has. Alaska's unique position as an Arctic State presents a variety of advantages to leverage and challenges to overcome.

I have to tell you, Alaska is clearly on the front line with dealing with the issue of climate change. We have our own task force set up. We have been active in it. We have focused on what we can do to mitigate the issues and these extreme changes in weather patterns that are impacting us on a day-to-day basis in Alaska.

Let me say that, as the President's Climate Action Plan moves forward and the State and local and tribal leaders' task force on climate change preparedness begins to develop recommendations, I am confident investing in mitigation is the right decision. We always spend the time, Mr. Chairman, always after the fact, picking up the pieces and the costs are huge. We had a hearing in Alaska through the Subcommittee that I chair here with FEMA and the Corps talking about what we can do before these situations occur when we know they are going to happen. We have 30-some villages on the list. We know they are going to fall into the ocean. Now, we can do something now, or we can wait until something bad happens, and then we are going to call FEMA, and FEMA is going to be writing some checks. That is the worst approach in the sense of dealing with this issue. We can do this in a much better way.

I know, Mr. Chairman, you invited an individual, Mike Williams, Sr., who is an Iditarod musher but also an incredible native leader from Aniak who was going to be on the panel today, but I know he could not attend. If I could just ask for the Committee to insert his comments and his testimony into the record, if that is OK.

Chairman CARPER. Without objection.

Senator Begich. Let me just end and say, Mr. Chairman, as the Chair of the Subcommittee on Emergency Management that deals with disaster relief, emergency preparedness, first responders, mitigation in this Committee, we have had several hearings on these issues, and I have sat here with insurance folks that talk about how they are adjusting their risk analysis, how they are making sure that they are now seeing more severe weather patterns, and they are not here to debate science. What they were here to say was that risk is greater. Patterns are changing. They are more compacted, and they are much more severe. So, therefore, the risk analysis goes into play and, therefore, rates go up. I know this as an owner of commercial property. I know my rates have not been flat for the last 10 years, because they are analyzing the risk and I get that. But there is a risk that everyone is paying today for the lack of action in regards to mitigating these situations.

So I want to again say to the Chairman, thank you for holding this hearing. It is a hard issue to grapple with because there are political views on climate change, but that is not the issue. The issue is it is happening. We can argue over it all we want. But in my State, we see it every single day. We have disaster after disaster. We have huge costs that are associated with it. And even though we are far away, 5,000 miles away, small villages, literally their buildings and houses are falling into the ocean. This is not

a hypothetical situation or theory. It is real.

So I really appreciate the work you are doing here, and I hope the Committee continues to talk about this. I know and I agree that we cannot bear all of the costs. That is just reality. But how we manage it, from everything from our building codes all the way up to what we do here on the Federal level, is critical to understand how we are going to manage this so we do not have these huge costs borne by the private sector, individuals, or the government.

So I look forward to this, and thank you very much.

Chairman CARPER. We are just glad that you could join Senator Johnson and me. Thanks so much for coming and for your comments.

Ron, when Senator Begich was speaking, I was reminded of, of all people, Senator Mike Enzi from Wyoming. And as my colleagues know, I oftentimes cite him. He may be here later today. But he has his 80/20 rule that is one of his guiding principles in terms of how to get things done. And the 80/20 rule is basically we agree on 80 percent of the stuff here in Congress, we disagree maybe on

20 percent. Let us just focus on the 80 percent that we agree on, and we will set the other 20 percent aside until another day. And today I think we are going to focus on the 80 percent that we can agree on and help chart a path for not just the Congress but for our country.

One of the people who is not here yet—he will probably be here in a little bit—is the Senator from Arkansas, Mark Pryor, and they have a saying in Arkansas: Whenever you see a friend—and Mark Pryor said this to me about a million times. He will say, "Hey,

man." And your name is Heyman. [Laughter.]

And I was just hoping Mark would get here so he could introduce you. He could say, "Hey, man." But, David Heyman, we are happy to see you, Assistant Secretary for Policy at the Department of Homeland Security (DHS). Mr. Heyman heads the office that is responsible for strengthening our Nation's homeland security by developing and integrating department-wide policies, planning, program, and strategies.

Caitlin Durkovich is the Assistant Secretary for Infrastructure Protection at the Department of Homeland Security. In this role she leads the Department's efforts to strengthen the public-private partnerships and coordinate programs to protect the Nation's critical infrastructure, assess and mitigate risk, build resilience, and strengthen incident response and recovery. It is nice to see you

again. Welcome.

And last but not least, Mark Gaffigan. Mark is the Managing Director for the U.S. Government Accountability Office's Natural Resources and Environmental Team. The Natural Resources and Environmental Team is responsible for GAO's assessments of Federal efforts to manage our Nation's land and water resources, protect the environment, ensure food safety, manage agricultural programs, ensure a reliable and environmentally sound energy policy, and meet our Nation's science challenges and address the United States and international nuclear security and cleanup. That is a lot to do for one person.

Each of you has about 5 minutes to read your opening statement. If you run a little bit over that, that is OK. If you go way over that, we will have to rein you in. The full content of your written statement will be included in the record, and with that, we are going to recognize Mr. Heyman, also known, as "Hey, man." Welcome.

TESTIMONY OF THE HON. DAVID F. HEYMAN, ASSISTANT SECRETARY FOR POLICY, U.S. DEPARTMENT OF HOMELAND SECURITY, AND CAITLIN A. DURKOVICH, ASSISTANT SECRETARY FOR INFRASTRUCTURE PROTECTION, NATIONAL PROTECTION AND PROGRAMS DIRECTORATE, U.S. DEPARTMENT OF HOMELAND SECURITY

Mr. HEYMAN. Well, thank you. A quick aside. Senator Pryor has said that to me for now over 30 years as I served as his vice president when he was a student government leader in my high school. His political career has skyrocketed because of my service to him. [Laughter.]

<sup>&</sup>lt;sup>1</sup>The joint prepared statement of Mr. Heyman and Ms. Durkovich appears in the Appendix on page 40.

Thank you, Chairman Carper—

Chairman CARPER. This story just keeps getting better. [Laughter.]

Mr. HEYMAN. Thank you, Chairman Carper, Senator Johnson, and distinguished Members of the Committee. And my best wishes to Senator Coburn and his family. It is a pleasure to be here this morning to discuss the impact of extreme weather and what the Department of Homeland Security is doing to improve the preparedness and resilience of our communities and Nation. This represents one of the most significant areas where we can all agree, I think. Investment today will help us save billions in the future.

Over the past decade, an unprecedented number of weather-related disasters—hurricanes, floods, droughts, wildfires, crop freezes, and winter storms—have hit the United States, leaving devastated communities and billions of dollars of damage in their wake. In 2011, we experienced 14 natural catastrophes exceeding \$1 billion in cost each. That is a record number. We had a record 98 presidentially declared disasters. In 2012, we faced Hurricane Sandy, the largest Atlantic hurricane on record and the second costliest to the Nation, damaging or destroying more than 300,000 homes in New York, 72,000 in New Jersey, and costing billions in damage.

According to Munich Re, the world's largest risk insurer, weather-related catastrophes over the past three decades have hit North America much harder than the rest of the world. Total economic losses in the United States total approximately \$1.15 trillion over the last 30 years. Without a concerted effort, national resilience effort, the trend is likely to continue.

The Department of Homeland Security is responsible for providing the coordinated, comprehensive Federal response in the event of a terrorist attack, natural disaster, or other large-scale emergency while working with State, Federal, local, tribal, territorial, and private sector partners so that we can ensure swift and effective recovery.

Over the past several years, we have made a significant shift in our thinking and in our practice of preparing for, mitigating against, and responding to disasters. And I can summarize that in one word: "resilience." Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and rapidly recover from disruptions.

In May 2009, President Obama took a significant step toward facilitating and institutionalizing national resilience when he merged the Homeland Security Council and National Security Council into a single structure and created a Resilience Directorate within the National Security Council. This Directorate manages resilience policy and operates alongside the Counterterrorism Directorate. This action established resilience as a Homeland Security pillar and priority which was called out for the first time in the President's National Security Strategy.

DHS affirmed this prioritization in its Quadrennial Homeland Security Review (QHSR), in 2010, promoting insurance of resilience to disaster as one of the Department's core missions and respon-

sibilities.

But the question is: How do you create and foster resilience? Establishing the concept of resilience in doctrine is an essential first step, but it is only one piece of proactively preparing for potential

disasters and readily responding to a situation as it occurs.

Across the Department, from FEMA to the National Protection and Programs Directorate (NPPD) to Science and Technology (S&T), we work with a wide array of government, private and non-profit, and faith-based organizations to build and foster resilience—not as a concept but as an applied reality. FEMA is leading implementation of the National Preparedness System. My colleague here today will discuss our critical infrastructure security and resilience programs. And in my office, the Office of Policy, we coordinate resilience initiatives and policy across the Department and are working to create the framework that fosters resilience and gives a coherent baseline. I would like to share one example of some of the important work that we have been doing.

We are creating a program called "Resilience STAR" based on the Energy STAR concept, which you probably are familiar with for appliances in your own home. In this case, it will help ensure that homes will be built to voluntary standards, stronger standards that will incur far less damage by disasters, protecting lives, livelihoods, and helping communities respond to and recover from disasters much more quickly. Ultimately, DHS aims to extend the Resilience STAR program beyond homes and facilities, and into critical infrastructure, helping to recapitalize the built environment across America in the long term, one home, one building, one bridge at a time. Our investments in resilience will pay significant dividends

for the country. It is efficient and it is cost-effective.

Homeland Security in the end is simply not about government action; rather, it is also about collective strength of the entire country. It is a shared responsibility that requires the participation of individuals, communities, the private sector, as well as State, local, and the Federal Government to be truly effective. The Department's Ready.gov website serves as a resource for citizens and businesses and communities so they can stay informed and take appropriate prepared measures.

This is, as I said, a shared responsibility that requires that we all work together to marshal all the resources to withstand whatever threats and hazards we may face. It is truly the actions of each of us that in the end will ensure the safety and security for

all of us.

I look forward to your questions. Thank you.

Chairman CARPER. Mr. Heyman, thank you very, very much.

Ms. Durkovich, please proceed.

Ms. Durkovich. Thank you, Chairman Carper, Senator Johnson, and distinguished Members of the Committee. I, too, extend my

thoughts and prayers to Senator Coburn and his family.

It is a pleasure to appear before you today to discuss the Department's efforts to enhance the resilience of the Nation's critical infrastructure to extreme weather. Our daily life, economic vitality, and national security depend on critical infrastructure. Infrastructure provides essential services and functions, but it is easily taken for granted. Often it is only when an incident occurs and service

is disrupted that attention is drawn to the importance of the infrastructure itself.

Threats to our critical infrastructure are wide-ranging, including aging and failing components, cyber threats, acts of terrorism, and climate change and extreme weather. The consequences of these threats to the public and private sectors can be seen in the events over the last decade. Hurricanes Katrina and Sandy, the tornados in the Midwest, wildfire and flooding across the Western States, the California drought, the extreme cold in the Northwest all demonstrate how weather can disrupt the availability of lifeline functions and other critical services.

Just as terrorist attacks threaten our communities, extreme weather disrupts the security of our Nation. Extreme weather strains our resources, diverts attention from counterterrorism efforts, serves as a threat multiplier that aggravates stressors both at home and abroad, and destabilizes the lifeline sectors on which we rely. Higher temperatures and more intense storms can cause inefficient infrastructure operations and damaging disruptions that can result in cascading effects across our communities.

Hurricane Sandy is a vivid example of the potentially devastating impacts extreme weather can have on critical infrastructure and demonstrates how interdependencies between infrastruc-

ture systems can magnify impacts and delay restoration.

Additionally, the increasing role of cyber and communication networks creates new vulnerabilities and opportunities for disruption. Two years ago, high temperatures and high demand tripped a transformer and transmission line in Yuma, Arizona, starting a chain of events that shut down the San Onofre nuclear power plant, disabling automated switching and distribution Supervisory Control and Data Acquisition (SCADA) systems, leading to a large-scale power outage across the entire San Diego distribution system. Strides have been made to address vulnerabilities that lead to such outages, but additional progress is needed to protect our interrelated systems.

The Nation must take a long-term perspective and account for evolving threats and hazards, including those caused by extreme weather that are linked to changes in climate, especially with regards to building resilience for critical infrastructure. Built infrastructure has a 10-year design build phase and a life span of 50 years or more and is expected to operate under stressor conditions

that sometimes we cannot even imagine.

As a result, it is a prudent investment to incorporate resilience into asset and system design, promote mitigation and built infrastructure, and to empower owners and operators with decision-making tools rather than to rebuild or redesign infrastructure after incidents occur.

To achieve infrastructure resilience, owners and operators must be able to minimize the disruption to essential services provided to our communities regardless of the hazard or threat; and when a disruption occurs, ensure essential services and functions are brought back to full operations as quickly as possible.

One year ago today, President Obama issued Presidential Policy Directive (PPD) 21, Critical Infrastructure Security and Resilience, and Executive Order 13636, Improving Critical Infrastructure Cybersecurity. PPD-21 directed DHS to develop an update to the National Infrastructure Protection Plan (NIPP), which was released in 2013. The NIPP 2013 envisions a nation in which physical and cyber critical infrastructure remain secure and resilient. Essential services and products continue to be delivered in the face of incidents, and communities and businesses adapt to changing conditions and rapidly recover from potential disruptions.

The Office of Infrastructure Protection (IP) is leveraging our core capabilities, such as information sharing, capacity development, vulnerability assessments, and situational awareness, to support owners and operators' efforts to strengthen resilience to weather.

owners and operators' efforts to strengthen resilience to weather. As a part of the Hurricane Sandy Rebuilding Task Force, IP and other Federal partners worked to develop the Infrastructure Resilience Guidelines, which are sound investment principles to guide Federal infrastructure investment as we modernize and adapt infrastructure—simple things such as consistent application of comprehensive science-based data and a regional cross-jurisdictional focus for selecting projects.

Additionally, I co-chair the new Infrastructure Resilience Work Group with the Department of Energy under the White House Council on Climate Preparedness and Resilience. Through this working group, we are coordinating interagency efforts on climate preparedness and resilience for the Nation's infrastructure. The working group is studying infrastructures most vulnerable to climate impacts throughout the United States and identifying risk-based mitigation and adoption strategies. This will inform and aid the critical infrastructure community with planning and decision-making regarding climate preparedness and resilience.

IP also works with State and local partners through the Regional Resiliency Assessment Program to examine a particular industry, region, or municipality's dependence on key lifeline sectors and to mitigate the hazards that could disrupt these complex ecosystems. This year, we are partnering with the State of Maine to produce the first Climate Change Adaptation Plan for the Portland metropolitan area.

In closing, by increasing the resilience of our critical infrastructure in our communities, we are better prepared as a Nation to the myriad of threats and hazards we face. Leveraging the partnership framework we have established over the past 10 years, IP will continue to work with owners and operators of critical infrastructure to understand the impact of extreme weather and to take steps to enhance resilience.

Thank you very much, and I look forward to answering your questions.

Chairman CARPER. Ms. Durkovich, thank you so much for your testimony. Stick around. We will have some questions.

Mr. Gaffigan, very nice to see you. Please proceed.

#### TESTIMONY OF MARK E. GAFFIGAN, MANAGING DIRECTOR, NATURAL RESOURCES AND ENVIRONMENT ISSUES, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Mr. Gaffigan. Senator Carper, good to see you again, Senator Johnson, thank you for inviting me here. Let me also extend best wishes to Senator Coburn and his family. I had the fortune to attend one of Senator Coburn's first hearings when he was on the Hill, and he told us afterwards he was going to do some oversight. And I think he has followed through on that, so I am very sorry

he is not able to join us today.

Chairman CARPER. And he has announced he is going to step down at the end of the year, and while he has some health challenges right now, he said that has nothing to do with those. It is just a personal decision he and his family have made. But I have said to him, "Well, you are still on the payroll for another 10-1/2 months, so I know you want to finish strong. And we are going to make sure that you do," and he is determined to. So plenty more oversight to come.

Mr. GAFFIGAN. Great.

I want to make three points. First, there is a lot at stake. We have all talked about the numbers in your opening statement. There are significant costs from extreme weather; not only to the Federal Government, but also to State, local, and tribal governments, businesses, farmers, individuals—in short, everyone.

Second, there is uncertainty about the specific risks we might face from extreme weather and how we can adapt to those changes and manage those risks. Complicating this uncertainty is that the risks faced and the appropriate adaptation is particular to the situations and the locations of those facing the risks. To borrow from the phrase "All politics is local," all adaptation is local.

Third, the challenge is to strive for the best, most updated infor-

mation to help inform specific preparation, resilience, and adaptation so that the investment, preparation, and resilience is most effective. And, as we have explained, funds are tight.

So let me illustrate what is at stake and describe challenges in

four areas that are particular to the Federal Government.

First, the Federal Government has a great deal at stake as an insurer of property and crops. In 2012, the National Flood Insurance Program had property coverage of over \$1.2 trillion while the Federal Crop Insurance Corporation covered \$120 billion in crops. That is a fourfold increase in the crop insurance coverage since 2003.

However, the National Flood Insurance Program has a debt of \$24 billion as of December 2013, as you pointed out, and the Nation's crop insurance annual costs have more than doubled from \$3.4 billion in 2001 to \$7.6 billion in 2012.

Back in March 2007, GAO did a study and found that both of these programs' exposure to weather-related losses had grown substantially and that FEMA and the U.S. Department of Agriculture (USDA) had done little to develop the information necessary to understand what those risks were. They have since developed reports. Now, those reports—USDA released its report in 2009. The Na-

<sup>&</sup>lt;sup>1</sup>The prepared statement of Mr. Gaffigan appears in the Appendix on page 51.

tional Flood Insurance Program released its report in 2013. They recognized the potential risks. They recognized the uncertainty. But it is still unclear what actions these programs are going to take in the future, and that will have a lot to say for the financial

solvency of these programs going forward.

But, also in 2012, Congress passed the Biggert-Waters Flood Insurance Reform Act, which, among many things, required the use of information on coastal erosion areas, future change in sea levels, and intensity of hurricanes to update its flood maps. Implementation of this law will be key in making changes to the National Flood Insurance Program.

Second, the Federal Government is a significant provider of disaster aid. The number of Federal disaster declarations increased from 65 in 2004 to a peak of 98 in 2011, and, as has been mentioned, FEMA has provided over \$80 billion in disaster aid during those years. And after Superstorm Sandy, Congress provided about

\$60 billion in budget authority for disaster assistance.

The Federal Government could do a couple things. It could start by fully budgeting for these costs to address the fiscal exposure that is largely outside of the budget process. And FEMA could also develop an updated formula—the formula has not been updated since 1986—to determine the capacity of jurisdictions to respond to those disasters.

Third, the Federal Government is the owner and operator of significant infrastructure. The Department of Defense (DOD) alone has over half a million buildings and facilities throughout the world, including some in vulnerable coastal areas. In addition, the Federal Government manages about 30 percent of the Nation's lands, forests, and wildlife. These natural resources face threats from extreme weather.

DOD has recognized the risk to its facilities and is trying to assess the potential impacts and consider what adaptation may be necessary at facilities in many different environments. And regarding Federal lands, the Federal resource agencies are also trying to incorporate climate-related information at the local level to decide what to do.

Fourth, the Federal Government is both an investment partner in public infrastructure and a potential provider of technical assistance. The Federal Government invests billions annually in public infrastructure projects. For example, the Congressional Budget Office (CBO) estimates that total public spending on transportation and water infrastructure is about \$300 billion annually, with about 25 percent of that coming from the Federal Government and the rest from State and local governments.

Our work has found that incorporating considerations about climate into the planning of this infrastructure that may be in place for 50 to 100 years can help avoid the need for assistance in the future because the infrastructure can withstand extreme weather. However, responsibility for planning and prioritizing these projects is primarily at the State and local level. And they may not have the information or expertise they need to incorporate climate considerations into their site-specific local projects. Thus, the Federal Government is in a position to be a provider of technical assistance, helping State and local officials identify and use the best available

information that is specific to their circumstances while also enhancing access to experts who could help translate that information at the local level.

That concludes my opening statement. I welcome your questions. Thank you.

Chairman CARPER. Thanks. Thanks so much, Mark, for the work that you-anybody here on your team, anybody in the audience from GAO, would you all raise your hand?

Mr. GAFFIGAN. The gentleman right behind me, yes. And there

are plenty more back in the building.
Chairman CARPER. Well, we just want to say on behalf of Dr. Coburn and myself how much we value the work that you do and appreciate the opportunity to partner with you.

Mr. GAFFIGAN. Thank you, Senator.

Chairman CARPER. I want to first talk a little bit more, about the Flood Insurance Program. Senator Johnson and I both voted against, as did Dr. Coburn, we voted against the flood insurance corrections bill that passed the Senate not very long ago, just earlier this month or late last month. And I go back in time to about 1990. I was a House Member on the Banking Committee and worked, believe it or not, I think with a guy named Tom Ridge, who was the ranking Republican on the Subcommittee that I chaired, and one of our focuses was the National Flood Insurance Program because we were concerned that the program was underwater. And here all these years later, it still is. And given the kind of changes we are seeing in weather, it is getting to be more underwater. And we adopted some changes to the legislation in the last year or two, and the costs as they come to bear on people who live in areas that are prone to flooding are in some cases very steep. There are concerns about flood mapping and so forth that people who were not living in areas where they used to have flooding, now they do. And so the question is: What do we do, if anything, in response to those conditions, those changing conditions, and to try to be humane but also to realize that there is a lot of money at stake here? I think doing nothing is not an option.

So the Senate has passed a bill—it is over in the House, and we are not sure what, if anything, the House is going to do, but my guess is that there will be an opportunity here to find a principled compromise that actually makes progress toward reducing this unfunded liability that is not cruel or heartless with respect to people

whose homes, whose businesses are at risk.

I know how closely you have been following what the Senate has done, the state of play, but if any of you have any advice for us as to how to proceed and what might be a principled-some of the elements of a principled compromise, I would welcome hearing those. And my guess is that we are going to have the opportunity later this year to work more closely with you and with the Administration. The Administration, the President is not crazy about this bill that the Senate has passed, as you know. So there is an opportunity for the Administration to weigh in and be part of the solu-

Any thoughts you have with us on that?

Mr. GAFFIGAN. Just very quickly, and, again, flood insurance is not necessarily in my portfolio. I have a lot of issues, but not that one. I think it is a tradeoff between the affordability of the program and the individuals who have to pay the premiums. At the end of the day, someone has to pay for this, and it is a question of the balance between the taxpayer and the individual businesses, and

homeowners, who own flood insurance.

I think some of the things talked about in Biggert-Waters relate to building in consideration of future risks. Trying to build in some resiliency going forward in that program would help minimize the risks so that we do not have to pay the higher premiums because we did not anticipate that high risk down the road. I think that is where the area of compromise is probably best sought.

Chairman CARPER. OK. Ms. Durkovich, Mr. Heyman, anything you want to mention on that before we go to another question? You do not have to. If you have something you want to say, go ahead.

Mr. HEYMAN. I just want to say that FEMA has actually been working closely with both the House and Senate on this. This is obviously a concern that we hear about, and I know that there are possibly going to be amendments down the road.

Right now, our authority is only to complete a study on affordability. We have no authority to address the affordability of actual flood insurance. But we are happy to work with you to help try to think this through.

Chairman CARPER. All right. Thanks.

I am going to come back to Mark Gaffigan for my next question. This deals with prioritizing risks. I think in your testimony you may have mentioned three or four areas where the government could limit its fiscal exposure when it comes to climate change and to extreme weather events. And within those three or four areas, which stands out to you for maybe the biggest fiscal concern?

Let me just add to that. This is kind of a P.S. Are there high-

risk areas that cannot be addressed by the Executive Branch and should be maybe of higher priority for my colleagues and me here

in the Congress?

Mr. GAFFIGAN. Well, you mentioned the National Flood Insurance Program. That is one in terms of fiscal risk, and I think it is hard to pick one that is more significant than others. And I just touched upon four areas. There are a lot of other potential impacts to the Federal Government.

We think the disaster assistance program, stands out, Congress

authorized \$60 billion for one storm, Superstorm Sandy.

Right now, as an owner of infrastructure, the agencies are trying to assess what is at risk. The Department of Defense has some serious concerns. They have at least 30 major facilities that are in coastal areas that are vulnerable to flooding. They have to be concerned about dry docks, making sure those are not exposed. So I

think that it is hard to pick a "most important" out of all those. Chairman CARPER. All right. A question for either Mr. Heyman or Ms. Durkovich or both, but in Mr. Gaffigan's testimony, he mentioned, as I recall, that infrastructure decisionmakers have not necessarily incorporated potential climate change impacts in planning for roads, in planning for bridges, in planning for waste management systems because they face challenges identifying and obtaining available climate change information best suited for their locations and for their projects.

Could one or both of you take a minute or two and just talk a little bit about how your agency is addressing this concern? In particular, I would like to hear how your agency is coordinating with other agencies to make sure that local planners have the best data possible, especially related to Superstorm Sandy rebuilding efforts?

Ms. Durkovich. Thank you very much for that question. In our unique role within the Office of Infrastructure Protection, we both have the ability to convene and coordinate with owners and operators, but with other members of the Federal interagency. Let me speak to that latter point first and two topics related to that.

First, I was in front of you a few months ago talking about Federal facility security, and I happen to chair a group called the Interagency Security Committee that works with 53 different departments and agencies to set standards related to Federal building safety and security. Climate change is an issue that this Interagency Security Committee is addressing and is working to incorporate it into its design basis threat scenarios, which are over three dozen scenarios that Federal buildings think about when incorporating protective and mitigation measures to, again, ensure the safety and security of those facilities.

So this is a group of physical security officers who are looking at how we address climate change when it comes to the over 300,000 Federal facilities that are in the area. We are dependent, though, as a Federal interagency on other lifeline sectors, and in the Office of Infrastructure Protection, we have the ability to convene our 16 sectors and partners both on the government side but also on the private sector side to talk about what they are doing to raise awareness, to look at best practices, to identify best practices, to help share those best practices to understand where the gaps are and to look at the comparative advantage that the Federal Government has and to think through what are some of the capabilities that we can bring to bear to help this effort.

And then just to speak briefly to the work that we are doing within the Infrastructure Resilience Working Group, this is, again, a unique opportunity to look across the Federal interagency and to look at the programs that are available to State and local communities to the owner/operator community, and to, again, understand what is working, where the gaps are, where we need to remove those barriers so that we can enable planning, that we can bring consistent comprehensive data to our partners so they can begin to incorporate it into their planning.

So a lot going on this front that I think we can continue to harness.

Chairman CARPER. All right. Before I yield to Senator Johnson, Mr. Heyman, do you want to add anything to that? Thank you for those comments.

Mr. HEYMAN. Sure. Thank you. As part of the National Preparedness Plan, we work very closely with States and communities to help them assess the threats and hazards and risks that they face. This is called the Threat and Hazard Identification and Risk Assessment (THIRA). Every State is required to do this. FEMA has a policy of making the best available data available, so that is to say, whatever is sort of the top-line scientific data that is available, FEMA tries to facilitate to the best of their ability.

Two years ago, there were only 15 States that had Climate Action Plans. Today there are 36 that have Climate Action Plans. They are incorporating the best data and the risk assessments to develop an action plan to better prepare their communities.

Chairman CARPER. Thanks very much. Senator Johnson.

Senator JOHNSON. Thank you, Mr. Chairman.

I am a big fan of a fellow named Bjorn Lomborg, who basically issues his report—I think it is called the "Copenhagen Project," and I believe he is an adherent of climate change, but he is also pretty good at prioritizing with limited resources where we should be spending our dollars. So I think my first set of questions really goes toward that prioritization. How do we do that? And are we doing it effectively? And can we be, for example, killing two birds with one stone?

I will start with you, Ms. Durkovich. You talked about cybersecurity, which brings to mind power grids, which brings to mind the attack at the Metcalf transmission station in, I believe, San Jose, California. There are a number of things that could affect our infrastructure: obviously natural disasters, weather disasters, as well as manmade terrorist attacks. Are we trying to combine these and take a look at that from the standpoint of prioritization of trying to mitigate problems?

Ms. Durkovich. Our role within the Office of Infrastructure Protection is to help owners and operators understand the range of threats and hazards they face, and as they look across their enterprise to manage risk, to provide them with information, with tools, with best practices so they can be both efficient and effective in ap-

plication of how they go about managing these risks.

Part of the reason that we have moved to a more all-hazards focus within the Department of Homeland Security and across the Homeland Security enterprise is that we find as you work to adapt preventive measures and mitigative measures to a range of threats and hazards, they are applicable not only to just one particular hazard but to many hazards. And so we work very closely with the owner and operator community to think through this. But let me touch briefly, for example, on the substation issue.

So as we think about security but also incorporate climate change and extreme weather into that conversation, as owners and operators are looking to invest in upgrades and to modernize that infrastructure, as they make improvements related to security, we can also have conversations with them about whether these assets and these facilities are in flood-prone areas, are in areas that are susceptible to sea rise. So as they start to make the multi-million-dollar investments that you are seeing, again, to enhance their security and resilience, we are thinking about these things in parallel, in an integrated fashion, and ensuring that the money that is invested in these enhancements and these mitigation measures is used effectively.

But again, our role is really to help them understand the range of threats and risks and consider measures and options that allow an efficient and effective application of resources.

Senator JOHNSON. Mr. Heyman, in terms of prioritization, are there lists being prepared? We talk about it. We talk about

prioritization. But is there any product that is actually ever produced?

Mr. HEYMAN. There is. The National Preparedness System has about five parts to it. One is to identify the risks. Two is to get a sense of where the gaps are, looking at communities based upon what capabilities are required for preparedness, then to do the resource assessment and ultimately resourcing followed by training and exercises, and you do that cycle again.

At the end of that exercise, there is a list of capabilities that are prioritized for communities, for States. Those States then apply for grants to FEMA based upon that gap analysis, and that becomes the basis for the next year's preparedness planning and evaluation, and so that is a regular cycle that is done. The National Preparedness Report is an annual report, and its last release was last year.

Let me just talk a little bit about prioritization as a concept because I think that everyone has said that mitigation is critically important, and I think that is right. There was a study done a few years ago by the Multihazard Mitigation Council which said a dollar's worth of investment up front in mitigation led you on the back end to \$4 back in terms of return on your investment. And, similarly, the Louisiana State University Hurricane Center evaluated what kind of benefit mitigation would have done in Hurricane Katrina, and they came back with a figure of \$8 billion would have been saved.

So how do we do that? One way of doing that, because the Federal Government does not own and operate most of the infrastructure and it does not own the residential housing or the buildings that are out there, is to try to incentivize and encourage raising standards as it pertains to the built environment. And the program I mentioned, Resilience STAR, which we are piloting in the residential environment this year, provides a basis for trying to look at how we can do that on a broader scale across infrastructure so that people are motivated and incentivized either through self-preservation, because their house will be the one standing, or through other incentives, whether it is mortgage reductions or perhaps premium reductions on insurance. And so we are looking at that, and I think that is something that this Nation should take a serious look at

Senator Johnson. Well, let us talk—because you are using the word I wanted to get to next is "incentivize." Where are those incentives best—where do they best come from? Private insurance market where you have basically millions of different decisions being made or from some centralized entity like the Federal Government trying to do it with a one-size-fits-all approach?

Mr. HEYMAN. So there are a number of different actors in this world. When you go to buy a house, there are the builders. Are they going to build it to code-plus standards? How do you get them engaged in that? As we are going ahead with the pilot, what we are seeing is that a lot of builders are interested in this because they see a market advantage. And so there is a benefit to being labeled, for example, Resilience STAR.

The insurance industry is interested in this because it saves them a whole lot of money on the back end with possible claims for damage, if you are looking at the life cycle of a house, every 40 years. And residential owners may see a benefit because—

Senator JOHNSON. Let me just stop, though. Wouldn't the insurance industry itself have a vested interest to develop these standards? And if they developed them themselves in the private sector, wouldn't it be more effective than a government-run solution?

Mr. HEYMAN. So insurers have looked at this. In fact, we are partnering with the insurance industry to try to develop this pilot project. And I think for various reasons, possibly because there are so many different fractured—you have a fractured insurance market, you have a number of different State players and all. I think one of the benefits that the Federal Government can bring is a national perspective, which is not something any individual insurance company can do.

Senator JOHNSON. Can I ask just one more question?

Chairman CARPER. Yes.

Senator JOHNSON. Because I have a great deal of concern. If the Federal Government is the 800-pound gorilla and everybody in the private sector is looking—or at the State level or local level is looking for the Federal Government to bail them out, is that a real disincentive to do the resiliency, do the mitigation efforts? If we have a big flood, if we have a big hurricane, the Fed is going to come in there and cover our losses and then some? To what extent are we witnessing that really throughout the country?

Mr. HEYMAN. Well, you are not, unfortunately, witnessing that. In many places, you have communities that are devastated, that people have packed up their bags and left, and you are losing your tax base. You are losing your ability to attract individuals to come to your community. And the Federal Government cannot help in

that regard when people move with their feet.

So this is one of those issues that I think local governments or urban communities will probably take a good look at, because if you are a resilient community sitting next to a zone which has a risk, people may want to be there because in the long run you are safer, more secure, and, frankly, the funds that you would have to pay in building your community can be paid to other priorities like public safety and education.

Senator JOHNSON. Of course, that is the point, isn't it, that we need to raise the price for individuals that are building in very risky environments, correct? We do not want to continue to incentivize people to be building in areas that we know are going

to flood every year or get wiped out every 10 years.

Mr. HEYMAN. And that is why it is important to have the best available data so that people actually are cognizant of where they are building or living or moving to. FEMA has tried to get that as a basis for getting data out, and then, frankly, when we work with communities to do their Threat and Hazard Identification Risk Assessment, that is all—with your eyes wide open, looking at what the highest risks are, and then asking if there is a way that we can partner together to reduce those risks.

Senator JOHNSON. OK. Thank you. Thank you, Mr. Chairman. Chairman CARPER. I wish we had time for another round of questioning. We have just learned that a series of votes starts at 11:30,

and I want to make sure we have good ample time to hear from our second panel.

I just want to followup, though, on what Senator Johnson is saying. We have had some demonstrations already on STAR programs, Energy STAR and some others that we are aware of, and just to make sure that we use those as laboratories of democracy, that we can figure out why they work and may be just as important as some that were attempted that did not work out. And I am one, like Senator Johnson, I am always interested in how do we align incentives in order to get the kind of behavior that we are interested in encouraging.

The other thing I like to do here, sometimes I quote David Osborne, who wrote a book back in, oh, I think the early 1990s called "Reinventing Government," and he talked about the role of government and the role of the private sector. And he used boats as the analogy. He said that the role of government is to steer the boat, the role of everybody else is to row the boat, so to actually do the work and to make it work. And so there is a good role for both, I think an important role for both, and hopefully we can find

the good balance.

I just want to say to each of you, thanks for the work you do. Thanks to the folks who work with you, and to say especially with respect to flood insurance, we will look forward to maybe working very closely with GAO and with DHS and others to try to find a principled compromise that makes a lot of sense. My father would say, if you looked at it from above, he would look at our final work on flood insurance and say, "Well, they used some common sense." So hopefully we will do that.

So, with that, you are excused, and we thank you for joining us, and there will be some followup questions. We just hope you will respond to those in a prompt way. Thank you so much.

[Pause.]

Collin O'Mara, all the way from—I want to say San Jose, California. Did you used to live in San Jose?

Mr. O'MARA. We did.

Chairman Carper. We stole him. Governor Jack Markell stole him from San Jose at the tender age, I think, of 29 or 30 to come all the way to Delaware to be our Secretary of Natural Resources and Environmental Control.

Ron, if I had half the energy of this guy, I would be President and Vice President. He is an amazing guy. I love working with him, very proud of the work that he does, and thank you for joining us today.

Our second witness is from a bigger State than ours—New Hampshire. Kelly Ayotte cannot be with us this morning. She sends her best. And Dr. Kirshen, research professor at the University of New Hampshire—what is your mascot there? Mr. Kirshen. It is the Wildcats.

Chairman CARPER. The Wildcats, yes. We have had some rough football Saturdays against the Wildcats, and the Blue Hens, but we are always happy to welcome you here. I understand your research focuses on water resources engineering and management as well as climate change vulnerability assessment and adaptation planning. So that is a mouthful, but we are happy that you could join us.

Thanks so much for coming.

And Ms. Lindene Patton—my mother was a Patton—chief climate product officer for Zurich International Group. In this role, Ms. Patton, I am told, is responsible for policy and risk management related to climate change. A member of my staff said that you might actually have a member of your family here or two. Is that true?

Ms. Patton. I do.

Chairman CARPER. Would you turn your mic on and just introduce whoever is here from your family? Maybe they will stand up or something.

Ms. PATTON. My daughters Amelia and Zoe.

Chairman CARPER. Amelia, would you raise your hand? Hi, Amelia. Zoe, would you raise your hand? All right. And who is in the middle?

Ms. PATTON. A friend of hers, Sharon.

Chairman Carper. Hi, Sharon. Nice of you to come.

Ms. PATTON. And our au pair, Gosia.

Chairman CARPER. All right. Ladies, thanks for bringing your mom.

OK. You heard me say to the first group take about 5 minutes or so, if you will, and then we will ask some questions. But we are delighted that you have come. Thank you so much. This is an important hearing, and I am happy to be here along with Senator Johnson to welcome you.

Collin, would you please proceed? Secretary O'Mara.

#### TESTIMONY OF COLLIN P. O'MARA,¹ SECRETARY, DEPART-MENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL, STATE OF DELAWARE

Mr. O'MARA. Senator Carper, Senator Johnson, our thoughts also go out to Senator Coburn. Thank you so much for holding this hearing today. I think your timing is good, and it is a critically important topic to Delaware as the lowest-lying State and one of the most vulnerable to these kind of storms.

Senator Carper and I spent a lot of time in helicopters and on the ground looking at the damage after the fact. That is in Delaware. We have actually probably done a better job preparing than almost any other State because of the way we are looking at it.

What I would like to do in my testimony is talk a little bit about Delaware's approach but then also offer some, I think, very commonsense solutions that should be part of the conversation going forward about shifting the focus to preparedness and resilience and a little less on the money on the back end.

In Delaware, our approach has been fairly simple. Start with the science and the economics and make sure you have good science and economics to know your vulnerabilities and the tradeoffs. it is easy in a political environment to move toward the thing that gets the most attention, but it is not always necessarily the thing that has the best economic imperative. And so we have done extensive analyses of our flood plains, and we have looked at sea level rise.

<sup>&</sup>lt;sup>1</sup>The prepared statement of Mr. O'Mara appears in the Appendix on page 64.

I have a particular here that I will introduce into the record with the Chairman's consent.

We have looked at 75 different types of infrastructure in the State and the vulnerabilities of each. Then we took that data to actually begin making infrastructure investments. We have looked at other climate impacts from temperature to more precipitation to more extreme storms, and really having that data drive our decisionmaking in a way that takes the politics out of it and really has the types of lists that Senator Johnson was asking about, having that strict priority list to make sure the limited dollars are going into places that make sense.

We have done an extensive analysis with Tony Pratt, who is behind me, who is our Administrator of Shoreline and Coastal Protection, looking at all of our bay beaches, and these are areas that do not really qualify for Federal assistance, and looking at the economics and who gets the benefit. And it turns out that most of the benefit is just the private owners, not to the broader population, which suggests that the private owner should pay rather than the

broader community.

We have also looked at the economic contribution of the coast and try to figure out the economic benefits of having protections. So having that kind of analytic rigor behind our decisionmaking is critically important because it then allows us to invest strategically. And we have a strong preference on natural systems. Senator Carper and I have seen places that have healthy dunes, healthy wetlands, places that build above code standards, are the ones that turn out very well after these storms. We see it time and time again. The communities that are not as prepared do not do nearly as well.

We are also taking a lot of steps to try to build resiliency into everything we do going forward, so modernizing storm water—we do not want to make the problem any worse. We want to stop the bleeding, and make sure that new developments are more resilient so now that we have this kind of data, that we are not exacerbating the problem and exacerbating the cost.

So because of all this, the Governor was actually invited to be on the President's Climate Task Force and really with a focus on this natural infrastructure and the natural resource projects that we have been doing across our State, whether it is in Wilmington or down in our inland bays and everywhere in between, we really are piloting projects that we believe can be a national model. So, with that, here are some commonsense recommendations for the Committee's consideration.

One, resiliency needs to be built into every single Federal investment. We do not need a new bureaucracy around this. We are spending billions of dollars every year on transportation, on wastewater, on community development block grant projects. If we build resiliency standards into those projects, we can make sure that money is spent a lot better. There is nothing more painful than seeing a project that has 80 percent Federal money and 20 percent local money wash away in a storm when it is only 10 years old, when we know if it was built better that would have survived. It is just throwing good money after bad.

The second is that we need to invest more in protection. We are spending \$5 billion in the Army Corps protection line through the Sandy supplemental. That is almost 50 years' worth of investment compared to what they normally get for their protection line. It is about \$100, \$150 million. We are spending \$5 billion in one year. If we spent \$300 or \$400 million a year on coastal protection, we could save ourselves tenfold that money in the years ahead. It just has become easier to pay for it after the fact as opposed to invest-

ing annually, and we continue to cut these lines.

Third, we really need to break this disaster-rebuild-disaster cycle that we have. It is still easier to rebuild to the old infrastructure standard that was there before the storm. You can get your money quicker through FEMA if we do that, as opposed to building something at a more resilient standard. We have seen it in Delaware with the dike repairs we are making in the northern part of the State, and there has been a lot of conversation about this, great recommendations coming out of Georgetown and some other places. But we need to make sure we are building to a higher standard when we are rebuilding, and I think there has been some good progress, but we need to figure out how to institutionalize and make sure money can move quickly as we are rebuilding to higher standards.

We also need to prioritize comprehensive projects. Right now, as we have talked about the Water Resources Development Act (WRDA) context, you can have two projects by the Army Corps: a navigation project that is taking a bunch of sediment out of a waterway, but it is cheaper to put that in a landfill than it is to put it on the beach next to it or the wetland next to it that actually could provide a protection project. The Army Corps right now will choose the lowest-cost option, and so they will not actually put it on the beach. They will move it somewhere else. We need to combine this. This is absolutely ludicrous. We could be saving tens of millions of dollars a year easily by putting those projects together and looking at the overall cost.

We need to make sure that sound science is continuing to drive the decisionmaking, particularly with our flood plain mapping. We

are doing a better job. There is a lot of progress there.

We need to update the NFIP regulations. They really have not been updated since 1989. We have been focused on the money side. But the cost of the insurance becomes a lot cheaper if the standards are higher. And so it is a way to actually mitigate the challenge that all of you are facing with constituents complaining about the high cost.

We need to prioritize natural infrastructure. We see the wetlands, the dunes, the living shoreline projects. They work. They work exceptionally well. They should not be the exception or the

pilot projects anymore. They need to become the default.

We need to stop rewarding communities that fail to prepare. Right now, a State like Delaware that has spent a lot of State money and a lot of local money does not receive as much after a disaster because our systems work, where a community adjacent to us might have spent very little money, they get everything paid for, they get all the new shiny infrastructure. It is completely crazy, and we need to make sure that there are incentives and priority

given to folks that have made their own investments and are really doing the hard work to hold themselves accountable and not relying on the Federal Government, as Senator Johnson said, where they are expecting the windfall after the fact without doing the work themselves.

The very two last points. We need to ensure that public expenditures produce a public benefit, making sure that we are not just subsidizing private activity but really prioritizing things that do

have a broader benefit to all taxpayers.

And then we need to have a much greater focus on hazardous sites. We talk a lot about coastal communities and residences and businesses along the coast. We have old Army landfills. We have national priority list sites, Superfund sites. When those sites wash out, the potential for catastrophic damage from these storms is massive. So we have been focusing on these in Delaware, but they are not receiving nearly enough attention, and there are issues right now; if you want FEMA to help you acquire a parcel, if the parcel actually is contaminated, FEMA will not touch it for Federal liability reasons. And so you end up buying another parcel that, will be less important. These are very commonsense things that we could change.

We are so grateful, Senator Carper, for you looking at these issues, because I think our experience in Delaware shows that if you do prepare, that ounce of prevention can be worth a pound of cure. So thank you, sir.

Chairman CARPER. All right. Thank you so much. Boy, he got a

lot in in 6 minutes and 50 seconds. Didn't he?

Mr. O'Mara. I apologize for going over. I always talk quick. Chairman Carper. That is all right. I was watching the body language of the co-panelists here, and Dr. Kirshen nodded his head up and down a whole lot. I think he may have agreed with one or two things that you said, but we will find out now.

Dr. Kirshen, thanks so much.

#### TESTIMONY OF PAUL H. KIRSHEN, PH.D.,1 RESEARCH PRO-FESSOR, ENVIRONMENTAL RESEARCH GROUP, DEPART-MENT OF CIVIL ENGINEERING, AND INSTITUTE FOR THE STUDY OF EARTH, OCEANS, AND SPACE, UNIVERSITY OF **NEW HAMPSHIRE**

Mr. KIRSHEN. Thank you very much. Thank you, Mr. Chairman, Senator Johnson, for giving me the opportunity to talk in front of this Committee.

I do agree very enthusiastically with everything Secretary O'Mara is proposing, and I hope to take some of his ideas back

with me to New Hampshire.

With the support of my colleagues at the University of New Hampshire and other institutions, I have conducted several studies on the long-term economic consequences of New England cities being impacted by, first of all, extreme amounts of precipitation and, second of all, coastal flooding from large coastal storm surges. Here I am going to talk about the long-term costs of not being prepared for these present and future events and compare them to the

<sup>&</sup>lt;sup>1</sup>The prepared statement of Mr. Kirshen appears in the Appendix on page 71.

benefits of being prepared. Because of the changing climate, climate change impacts have always been part of my analyses.

I also want to point out that while the case studies are particular to New England, the findings are relevant to many parts of the United States—in fact, the world.

One of the first studies I am going to talk about was the impacts of coastal surge flooding on the eastern coast of Massachusetts, the region stretching from north of Boston to almost Cape Cod. This is an area of large cities like Boston but also suburbs. And there we looked at the total damages from surge flooding from storms to residential, commercial, and industrial buildings over the next 100 years assuming several moderate, plausible sea level rise scenarios, and we looked at the damages and compared them with where the damages were reduced if adaptation had taken place, and we measured the benefits of adaptation by damages avoided and measured the cost by the cost of adaptation, and we found benefit/cost ratios ranging from 6 to 30 for urban areas and 9 to 13 for suburban areas. So what that means, for example, a benefit/cost ratio of 6:1 means that every dollar invested in adaptation reduces long-term damages by 6 times. So these are, again, showing the true benefits of preparing for these present and future events.

Our second case study was the Hampton-Seabrook-Hampton Falls area of New Hampshire. It is a coastal area of New Hampshire with many second homes, particularly on the barrier beaches of Hampton and Seabrook. And here we looked at the benefits and costs of protecting privately owned buildings—in other words, homes and commercial facilities—and also key public assets, such as sewage treatment plants, schools, fire and police stations, from present and future coastal storms by, again, developing adaptation plans to protect to 2050 under low and high sea level rise scenarios of approximately 1 feet to 2 feet. And, again, we found very large benefit/cost ratios ranging from 11 to 16 for private assets and 7

to 8 for public assets.

The last case study is managing storm water in the Winter Hill section of Somerville, Massachusetts. This town is located north of Boston and Cambridge on the tidal Mystic River and is one of the most densely populated municipalities in New England. This area is served by a combined sewer system which carries both storm water and sanitary waste. Presently, the storm system—the sewer system only has the capacity to handle all the wastewater and a small amount of the storm water. But when a larger storm occurs, like only 1 inch of rainfall, some of the extra combined sewage is treated at the regional wastewater treatment plant, but most of the combined waste is discharged partially treated into the Mystic River, and there is flooding in the streets with raw untreated sewage. And this performance of the system is going to be further stressed by increases of extreme rainfall of 10 to 30 percent by 2070 and higher sea levels in the Mystic River.

So, again, we did a benefit/cost analysis comparing the cost of adaptation and preparing the sewer system to handle more waste with the benefits to be avoided by adaptation, and we found benefit/cost ratios of about 4:1, again, showing the advantages of deal-

ing with these problems now rather than later.

So to summarize, I have talked about some of my recent research on the benefits of urban adaptation to climate change compared to the costs of damages. Actually, the costs I talk about may actually be underestimated because I do not include in my costs such items as human deaths and injury, damages to ecosystems, indirect costs such as lost employment and business activities, and community displacement and disruption. But even with these costs not included, we found that over many scenarios of climate change and sea level rise, adaptation paid off in terms of damages avoided. And undertaking no adaptation, no action, in all cases was the worst thing to do. And, also, with these benefit/cost ratios so high, all greater than 4, this to me would indicate that these actions are useful even if we did not have climate change. These are so-called no-regret actions.

So I just want to say a couple more comments. First of all, one of the first steps we can take to better control these threats from climate change is to control emission of greenhouse gases. That will make a big difference whether we have 3 feet of sea level rise by the end of the century or 6 feet, also whether we have a 10-percent increase in extreme rainfall or 30 percent. But because we cannot reverse climate change, we cannot change climate change, climate change is going to continue for centuries, we have to adapt, be prepared. And like everyone else here, I really support we undertake planning now to start dealing with these threats; otherwise, we are going to be suffering large human, social, and environmental con-

sequences.

Thank you for your time.

Chairman CARPER. Thank you for coming all the way from New Hampshire to be with us today. Tell those Wildcats we said hello, and thanks for sending you down to spend some time with us.

Ms. Patton, your whole statement will be made part of the record. Please proceed.

#### TESTIMONY OF LINDENE E. PATTON, 1 CHIEF CLIMATE PRODUCT OFFICER, ZURICH INSURANCE GROUP, LTD.

Ms. Patton. Thank you very much. Chairman Carper, Ranking Member Johnson, thank you very much. My name is Lindene Patton. I serve as the chief climate product officer for Zurich.

Zurich is a global insurer providing insurance and risk management solutions to customers in 170 countries. We have been serving customers in the United States since 1912 and today stands as the third largest commercial property casualty insurer in the country, with over 8,000 employees nationwide.

I would like to thank you for holding this timely hearing, and I am pleased to share with the Committee an insurance industry perspective on the current State of our Nation's resilience to extreme weather events and the economic importance of investing today in improving resilience.

Zurich observes that the United States is increasingly reliant on disaster recovery funds to respond to extreme weather events and is underinvested in resilience—both physically and economically.

<sup>&</sup>lt;sup>1</sup>The prepared statement of Ms. Patton appears in the Appendix on page 79.

Data show that the number of loss-relevant weather catastrophes has increased from an average of 400 per annum in 1980 to over 1,000 per annum in North America today. The Federal disaster relief expenditures alone over the last 3 years have risen to \$400 per household. That is more than a fourfold increase over the past 30 years. In other words, the resilience gap is large and growing.

How large? In 2010, Professor Cummins projected that over the next 75 years costs for the Federal Government share of unfunded response costs for weather-related disasters would grow to more than US \$1 trillion and might be as much as US \$5.7 trillion.

Unfunded exposures of the State catastrophe funds are in addition to this number and have been projected to be at \$3 trillion.

Taxpayers are bearing the burden of this increasingly unbudgeted risk and associated loss costs. Without decisive risk reduction action by government as well as insurers, economically unsustainable accretive unbudgeted disaster management costs can be expected to continue on an upward trajectory.

Insurance has a unique capacity to facilitate resilience, providing risk assessment, risk management, and risk-based price signals, all of which help inform stakeholders about risk magnitude and risk reduction priorities. A study by the Bank of International Settlements found uninsured and underinsured economies are more likely to suffer long-term macroeconomic damage. Some may believe that ex post disaster recovery funding takes the place of insurance, but it does not.

One of the many critical differences is that disaster recovery funds typically are delivered more slowly than insurance payments, resulting in slower recovery and even longer-term negative economic impacts. But assuring resilience to extreme weather events requires risk management before, during, and after a loss event. If our response to extreme weather events is only after they occur, society has squandered its best opportunity to control risks and costs related to these events.

So should resilience be prioritized over other disaster response costs? Absolutely. Why? Investment in resilience saves taxpayers billions of dollars, provides greater protection to the public in the face of increasing extreme weather events, reduces human suffering, and creates domestic jobs and promotes domestic manufacturing in building more resilient housing and infrastructure.

Zurich understands the importance of pre-event investments in resilience and acts accordingly. We are very proud of our efforts. Here are but a few examples.

Zurich has supported the following institutions and work focused on resilience improvement including: the World Economic Forum, the Business Continuity Institute, the Institute for Building and Home Safety.

Over the years, we have worked with progressive customers like Marriott and Verizon to demonstrate by design and implementation cost-beneficial extreme weather event risk mitigation solutions. Zurich has committed to purchase \$1 billion U.S.D. of green bonds focused specifically on resilience, making Zurich a global leader in the purchase of such resilience-supporting instruments at a scale that really matters.

What action might the government take in the short term, medium term, and long term to close this resilience gap? Develop a national priority plan for resilience investment. Promote increased government and private investment in infrastructure resilience, educate society on the true costs of extreme weather, and promote and enforce stronger building codes.

Two specific actions Congress could take to improve resilience

might include:

Use the language of the Extreme Weather of the Water Resources Development Act as a template to improve resilience requirements framing the billions the Federal Government invests annually in water, port, highway, transit, and aviation infrastructure.

They also might expand the Resilience STAR pilot currently proceeding at DHS to include commercial applications and, most im-

portantly, entire community resilience ratings.

How much should be budgeted? It might be logical to take a portion of the predicted emergency disaster appropriations and use it to improve resilience in assets. From a practical perspective, funding resilience is a fundamentally wiser investment than spending on disaster relief and recovery. The Multihazard Mitigation Council found that funding resilience provides a 4:1 return on investment. Our co-panelists noted other studies which have indicated similar or improved returns on investment.

As the incidence and costs to the Federal Government of extreme weather events increase, so does the budget imperative to make

greater investments in resilience.

In conclusion, Zurich believes that we have an opportunity to dramatically improve the resilience of our Nation's homes, businesses, and critical infrastructure and that this can be achieved in a manner that will ultimately save Federal, State, and local governments billions of dollars annually while providing citizens greater protection from extreme weather events. Zurich is extremely encouraged by this Committee's efforts to improve our Nation's resilience and looks forward to working with the Committee in any way that we can help.

Chairman CARPER. Great testimony. Thank you very much for

that.

I am going to slip out of the room and take a phone call, and Senator Johnson is going to lead off with the questions for this panel. I will be right back. Thanks.

Senator JOHNSON. [Presiding.] Thank you, Mr. Chairman.

Ms. Patton, I would like to start with you. You mentioned a growing resilience gap. How much of that gap, especially the growth of it, would you attribute to the fact that we have just con-

tinued to build in very risky areas in this country?

Ms. Patton. I am not in a position here to identify the percentage or a precise number, but it is substantial. We simply have more assets in harm's way. We have a history and there is a lot of data and research which indicates that we have a migration to coasts. We have a migration to locations which have limited water supplies. We have migration to the wilderness-urban interface (WUI).

Under all of those circumstances, you put more assets in harm's way, so the suggestion is that at least that is a portion of the driver, but we also have other suggestions that the climate is changing. There is no question.

Senator JOHNSON. Now, when society subsidizes private individuals taking those types of risks, that increases that type of behav-

ior, correct?

Ms. Patton. And there is research, which I have cited in my written testimony, which does demonstrate that. In fact, if there is an interference with risk-based price signals and a subsidy which basically provides information to an individual that moving to this location is not that cheap and if there is a disaster it will be subsidized, then yes.

Senator JOHNSON. Well, we have that interference, correct?

Ms. PATTON. We do.

Senator JOHNSON. What would cause that interference, from your

standpoint?

Ms. Patton. Well, there are a multitude of things. Some of it is actual funding and some of it is perceptive. So in the case of actual funding, there are programs which come in and provide subsidies for government-run insurance programs. There are also circumstances where there are perceptions—and there was a study done by a Federal task force after Hurricane Sandy which was trying to look into what people understood about their insurance, and what that study revealed was that people really did not understand what was insured and what was underinsured. And their assumption was that Federal disaster funds would be delivered kind of like insurance.

Senator Johnson. They were correct, weren't they?

Ms. Patton. Well, the reality is, in fact, the priorities for Federal disaster funding is to really look at getting critical infrastructure up and started, but not necessarily always focused on an individual asset, which is the purview of private insurance. And they are a not a 100-percent substitute, and I have cited research in my written testimony that affirms that, that demonstrates that, in fact, disaster recovery funds do not have the same economic value that you have from private insurance and that you can have longer-term negative macroeconomic impacts if you are underinsured versus having adequate insurance.

Senator JOHNSON. As necessary as Federal help is in those cir-

cumstances, it creates moral hazard, does it not?

Ms. PATTON. It is very clear that under circumstances the Federal Government must respond under disaster. It is a political imperative.

Senator JOHNSON. Right.

Ms. PATTON. It is a social imperative. But how you manage and structure that is very important, and as some of the other co-panelists have suggested, there are ways to prioritize that spending, and there are ways to structure programs in terms of providing information and risk-based price signals that are consistent. There have been recommendations that have been made by the Wharton School as to how some of those risk-based price signals might be adjusted in a way for certain Federal insurance programs. There

are other suggestions that exist in terms of prioritizing infrastructure investment so that resilience is baked into the design.

Senator JOHNSON. Do you think people would build \$1 million, \$2 million homes right on the beach if they had to pay the full cost of the risk on their insurance?

Ms. PATTON. I do not think I am in a position to know that.

Senator JOHNSON. You come from the insurance business. Is it a fantasy to think that we could over time privatize the Flood Insurance Program?

Ms. PATTON. I think that that will be a question that I will have to return to you on in terms of responding in full. I would tell you that I think it is very important for us to send consistent risk-based price signals in this context and let the market work.

Senator JOHNSON. And that is not happening right now with the National Flood Insurance Program, correct?

Ms. Patton. There are changes to that flood insurance program—

Senator Johnson. Which we suspended.

Ms. Patton. Which are designed to allow that.

Senator JOHNSON. OK. And, again, that is not a good thing in terms of reduction of that moral hazard of——

Ms. Patton. The position of Zurich is—

Senator JOHNSON. And you are really creating the incentive for risk management and risk mitigation and resiliency creation, correct?

Ms. Patton. Absolutely. I could not agree with you more. It is very important that the risk-based price signal and the insurance functionality be permitted to make sure that risks can be assessed, the asset owners can be fully informed about what, not only the actual functional risk is, but what the cost of that risk is so that they can make cogent decisions about how they invest. Not only where they invest, but when they put structures together, how much they invest.

Senator JOHNSON. OK. Now, we are talking about private individuals, private property. But at the same time, government has property which they also purchase insurance for, correct?

Ms. Patton. Well, there is something called the "self-insurance rule" under government, and there are—it depends on whether you are talking about local, State, or Federal Government. And in general, the Federal Government is primarily a self-insurer, and when it—

Senator Johnson. Does that reduce their incentive to mitigate risk——

Ms. Patton. It is their money.

Senator JOHNSON [continuing]. In your opinion? I mean, if they were forced to buy insurance, not self-insure, would they potentially—because within their budgets, if they are building and not mitigating risk, would that help mitigate risk?

mitigating risk, would that help mitigate risk?

Ms. Patton. The only thing I can point you to is that there is a longstanding Comptroller General's opinion, which dates back to the 1700s, which indicates that the Federal Government is supposed to be a self-insurer by rule, and there are policy reasons for that. But the functionality of private insurance, you are absolutely

correct, is to send a risk-based price signal to encourage people to mitigate risks so that they can control those costs over time.

Senator JOHNSON. Well, as you said in your testimony, the insurance industry has a unique capacity to provide that discipline.

Do either of you two gentlemen want to comment on that line of

questioning?

Mr. O'MARA. I think I would just add that the problem that we are seeing kind of continuously is that folks see themselves as libertarians until they need help because they have not taken care of the private markets. And so, we are trying to figure out ways in Delaware, particularly in one of our counties where they do not have some of the more protective policies in place, to not have State government in this case be the backstop because they are not getting private insurance and you do not have the policies in place, and then they are coming to us and saying, "Will you fix this drainage issue, this erosion issue?" So trying to realign those incentives is the same issue whether you are local or national.

Senator JOHNSON. OK. Dr. Kirshen.

Mr. KIRSHEN. I am not an expert on insurance, but I know if water rates go up, people start to conserve. So I think it is very important we send the right market signals for climate change preparedness as well.

I also want to say that I think the engineering and the science community and the social science community, I think we know how to do adaptation, and we need to send the right signals to the market to give us the opportunity to work with stakeholders to implement adaptation.

Senator JOHNSON. OK. Again, thank you all for your testimony. Thank you, Mr. Chairman.

Chairman CARPER. [Presiding.] Thank you.

I just asked my staff to double-check to see when we passed the omnibus appropriations bill, if there was a 2-year stay on the effective implementation of the flood insurance, changes to the laws that were—was it Biggert-Waters legislation? And my understanding is that there is a 1-year stay, but I think it expires at the end of this fiscal year. So there is a great opportunity for us to take some of what you said here today and to work with the Administration, who is not wild about the legislation that the Senate has passed on flood insurance, and to work especially on this Committee and to see if we cannot make sure that we are properly aligning the incentives to advise folks to do what they need to do so that it does not all fall on the taxpayers.

I notice out in the audience Tony Pratt. Collin O'Mara referenced him by name, and, Tony, it is great to see you. Thank you so much for all the good you do for the people of our State and really the example that I think you help set for folks in other States as well.

You said something, Ms. Patton, in your testimony—I think you mentioned some actions that Congress could take to improve resilience, and you said—I am just going to read it. The first one is pretty short. It says, "Use the language of the Extreme Weather Title of the Water Resources Development Act as an example of what could be applied to improve the resilience requirements framing the hundreds of billions of dollars the Federal Government invests annually in water, port, highway, transit, and aviation infra-

structure." And I think at that point, I looked at both of your colleagues as witnesses, and they were both vigorously nodding their heads up and down. I think I know why, but I am going to ask them. Secretary O'Mara, why were you so effusive in your response

to Ms. Patton's testimony at that point?

Mr. O'MARA. Right now, I mean, there is a significant disconnect—and it is not just within WRDA; I mean, it is also kind of other appropriation bills—where the design standards have not kept up with the risks. And we saw this, frankly, in Delaware at the Indian River Bridge where we built a beautiful new bridge, \$150 million, but we were not successful working with the Army Corps to bring the protection necessary through our cost sharingwe were happy to pay our share—of a dune system to protect that asset. And so either having a better design or more protection, kind of across business lines and across agencies, is critical. And so whether it is the authority through WRDA or just additional language in the authorizations and making sure that the designs are stronger across all those—it is not just transportation, but wastewater and the community development block grant in particular, I mean, those are the lifeblood of many municipalities and States in terms of delivering projects. And having that especially with the cost share, having more accountability in there, could save a lot of money in the long run.

Chairman CARPER. All right. Thanks. Dr. Kirshen.

Mr. KIRSHEN. I am not going to say too much because I am not a real expert on this, but just like——

Chairman CARPER. That never stops us from weighing in.

Laughter.

Mr. KIRSHEN. But I am going to say that from my observations working with communities, there are many institutional barriers to adaptation, and we have to address them as well as the financial ones. This is an example of some of them.

Chairman CARPER. OK. Thanks.

The next question will be for, I think, probably Secretary O'Mara and Dr. Kirshen. Mitigation can, as we know, be very cost-effective in reducing lives lost and damages caused by natural disasters. I believe we have had a lot of success with mitigation in Delaware, in part because of the fellows that are sitting here in front of us today. I think we have done it with a relatively small investment, saving our State a lot of money. And I would just ask a question, if I could, of you, Dr. Kirshen, and then one of Secretary O'Mara. But, Dr. Kirshen, based on your research, how beneficial is extreme weather mitigation, especially long-term planning and when it comes to saving money?

Mr. KIRSHEN. Well, I think, as I said earlier, we are getting extraordinary benefit/cost ratios, if we really look at the benefits of adaptation versus doing nothing, benefit/cost ratios of, 4 up to 30 in some cases. So it is extremely beneficial to do this. And I think communities realize this. I am working with quite a few local communities in Massachusetts and New Hampshire on adaptation. Communities get it because they are in charge of infrastructure, and they are looking for help in how to do this. I mean, it is more than just giving them the data. They also need people to help them interpret the data and also think about how to use the data in

planning for climate change. The problem with climate change is the uncertainty. We are not exactly sure what the future climate is, but we know how to deal with uncertainty through scenario analysis and other decision and analytical techniques.

So I think we have to provide support to the communities to do planning, which is relatively cheap compared to the huge costs we

are going to face if we do not do good planning. Thank you.

Chairman CARPER. OK. Thank you.

And, Secretary O'Mara, just to followup on that, based on your experiences, what needs to be done to encourage and support State and really local governments, too, to support individuals and businesses to adopt mitigation measures such as adapting or adopting updated building codes to better address the threats of extreme weather?

Mr. O'Mara. Yes, I think there are kind of two pieces to the equation: one deals with something Senator Johnson was raising about the economics and making sure the economics of inaction are very clear to folks; and then also, kind of toughening up a little bit and making sure if folks do not take those actions, that government does not, come in and bail them out after the fact, which is obviously always the easier political outcome, and if we are able to do those things, you will see behavior change fairly quickly. I mean, the money is going to drive a lot of these investments.

I do think that there are significant opportunities for the Federal Government to incentivize and reward those communities that take the types of actions that we have all been talking about. And so whether that is earlier consideration for Federal resources, whether it is, you know, competitive grants, or even having a slightly higher percentage for either percentage allocations for match or other types of Federal assistance, where if you have done the hard work, it is going to save the Federal Government money in the long run. Because, for example, in Delaware, we did not have individual assistance claims that met the FEMA threshold after Sandy because most of our systems worked. Our dunes worked. Rehoboth was intact. We were not hit as hard as some other States, but there are States to the south of us that received a lot of Federal money, and we did not really receive any from the Housing and Urban Development (HUD) because our systems were successful. We should be either rewarded or incentivized in some ways. And the other States that do not take those actions should be penalized in some ways.

And I think aligning those incentives, as you have often talked about, is some work that this Committee I think could really lead on and really align some incentives to drive great investments at the local level.

Chairman CARPER. All right. Thanks for saying that.

Ms. Patton, if I could, a question for you. With the insurance companies having a long history of risk management when it comes to extreme weather events, are there ways to create more public-private partnerships to help share the knowledge between Federal and State and local governments?

Ms. PATTON. I believe that there are, and I think it is very important to continue those and to take those exemplars that you have which are ongoing and expand them. As I mentioned earlier

in my testimony, I am very excited about the Resilience STAR pilot at DHS. It provides a framework——

Chairman Carper. So am I. Let the record show so am I.

Ms. Patton. It provides a framework in which we can actually and we are collaborating in a public-private partnership context. We are just at the beginning of this pilot, but I can see it very easily extended to the commercial and infrastructure context. And when that happens and you can actually create a resilient community, it would enable other private sector opportunities. Other types of incentives may present themselves. If you have a resilient community, it may be obvious that that might be a really good place to invest. It might be obvious that the risks where loans are placed under those circumstances are reduced. It is not just about insurance. It is about the long-term functionality and economic resilience of that community to be able to survive and thrive even before, during, and after extreme weather events.

That is just one example. I think that to the extent that some of the other recommendations of the panel can be followed through in terms of providing opportunities with infrastructure investment and matching funds, that will provide other opportunities for pri-

vate sector to inject themselves into the process.

Chairman CARPER. All right. Thanks.

One final question, and I am going to ask you to make just real brief answers because our votes have begun. As you know, we are at a time when we are trying to further reduce our Federal spending. It is down from a \$1.4 trillion deficit 4 years ago to this year it will be about \$550 billion. But as a result, some of my colleagues have been critical of extreme weather mitigation efforts because they cost the Federal Government money, such as beach replenishment for coastal communities, but other things as well.

What are the counterarguments to those who say that taking the steps needed to build resilience are really too costly and, therefore, should not be taken? And do you have any parting advice to us on how we can better plan for extreme weather events and reduce financial risks to our government? I would ask you to wrap it up fairly briefly, but, Secretary O'Mara, would you close us out with that?

Mr. O'MARA. Sure. I think we let the economics speak for themselves. I think that, if we can say that an extra dollar invested in the Army Corps' protection line is going to save you \$5 or \$10 on the FEMA budget, that is a compelling argument. I will take a 5:1 return any day.

The same thing can be said for many other types of infrastructure investments today, and I think there is a huge opportunity right now because we do have data that we could collect fairly easily between communities that were well prepared before Hurricane Sandy and ones that were not as well prepared before Hurricane Sandy. We should be collecting that data as we speak to make sure we know the costs to the Federal Government for communities that were not prepared.

Now, you have two communities in New Jersey, for example, one had healthy dunes, one did not. The one without healthy dunes is getting significantly more money. We should be quantifying that because that could help make your case to your colleagues about the cost savings from making the investments up front.

Chairman CARPER. Good. Thanks. Very briefly, Dr. Kirshen? Mr. KIRSHEN. I agree with Secretary O'Mara, but, again, as everyone said, an ounce of prevention is worth a pound of cure.

Chairman CARPER. You have got it.

Mr. KIRSHEN. And I think that is the solution. Chairman CARPER. Good. Thank you. Ms. Patton.

Ms. Patton. I would also agree that economics do speak for themselves. I think it is not just about the expense. It is about the potential interruption to the gross domestic product (GDP) for the impacted regions and about the potential for actual communities to no longer exist or to be severely interrupted not just for weeks but for years and to not be restored to what they were before. So the investment and resilience has both direct economic value, but it also has social value in the short term and long term.

Chairman CARPER. Let me conclude. First of all, thank you, thank you all. You have a lot going on in your lives, but we are grateful that you took some time to spend this morning with us.

grateful that you took some time to spend this morning with us. The other thing, I go back to what I said as we were beginning this hearing—Mike Enzi, the Senator from Wyoming, one of my favorite colleagues, I think everybody loves Mike Enzi here. But his 80/20 rule, and how do you get a lot done? Focus on the 80 percent where we agree, set aside the 20 percent where we do not agree. There is a lot of agreement here.

One of the things I love, this could have been a fairly controversial hearing or a combative hearing. It was not at all. Senator Johnson came, and I am grateful that he stayed, and he stayed a lot longer than he had actually frankly anticipated staying because he thought it was worthwhile. And there is a good deal that we can agree on and work together on, and that is what the people of America sent us here to do.

So I just thank you for helping us to find that 80 percent, find the middle, and we are going to have some more questions that folks will ask of you. Some who were here, some Senators who were not here will submit those questions, and I think they have about 15 days to do that. And if you receive any of those questions, if you could respond promptly, we would be most grateful.

And with that, this hearing is adjourned. Thank you so much. [Whereupon, at 11:47 a.m., the Committee was adjourned.]

### APPENDIX

#### Opening Statement of Chairman Thomas R. Carper Extreme Weather Events: The Costs of Not Being Prepared February 12, 2014

As prepared for delivery:

Good morning and thank you for joining us today to talk about the true costs of not preparing our

Unfortunately, extreme weather appears to be the new norm. Events like Superstorm Sandy, recent wildfires, dangerous tornados, and historic droughts may well be just the tip of the iceberg of what's to come

And even today, the East Coast is preparing for yet another snow storm while the West Coast is experiencing a historic drought and increased fire danger with no end in sight.

For years, I have been working with many of my colleagues to address the root causes and unfolding effects of what I believe is one of the biggest challenges of our generation – climate change.

According to the United States Global Change Research Program, extreme weather events have increased in frequency over the past 50 years and are expected to become even more common, more intense, and more costly.

But today's hearing is not intended to hash out climate science. Instead, it is about finding common ground.

As our country debates how to address our changing climate and the extreme weather I believe it is likely causing, our witnesses will deliver to us a clear message. Put simply, the increase in frequency and intensity of these extreme weather events are costing our country a lot - not just in lives impacted – but in economic costs, as well.

For example, the damage from a storm still fresh in many of our minds - Superstorm Sandy, which impacted my home state of Delaware and many of our neighbors – is estimated to have cost our economy \$75 billion in financial damages. And that's just one storm.

We're also hearing reports about the devastating effects of California's severe drought and how it is impacting the wildfire season in that state and across the West. Not only are wildfires growing in frequency and severity, but we are now seeing severe fires and wildfire conditions in winter and spring, well beyond the traditional wildfire season of summer and early fall. These fires are enormously expensive to fight and to recover from, and they pose serious threats to lives and property, damaging homes and businesses alike.

According to a 2013 report by insurance company Munich Re, the nearly 40 wildfires last year in the United States cost our economy \$1.1 billion.

These economic damages can deliver a devastating blow to many local communities and states, as well as to the federal government.

The Federal Emergency Management Agency (FEMA) alone has obligated over \$80 billion in federal assistance for disasters declared during fiscal years 2004 through 2011.

However, the cost to the Federal government is not just limited to disaster relief. As an insurer of both property and crops, the government faces additional significant fiscal exposure.

For example, since the creation of the National Flood Insurance Program in 1968 through December 2013, FEMA's debt from insurance payments to that program have totaled approximately \$24 billion.

Even before Superstorm Sandy, the total debt from payments through the National Flood Insurance Program was \$17.8 billion.

The costs of these weather events keep going up at a time when we are trying to bring government spending down.

That is one of the reasons why, for the first time,, the Government Accountability Office (GAO) last year listed climate change as one of the biggest fiscal risks facing our country in its High Risk List report.

In response to this historic GAO announcement, House Oversight and Government Reform Chairman Darrell Issa, stated: "the Comptroller General has made it very clear that we have not prepared properly, that the federal government has a financial risk that we have not properly mitigated, I think is a wakeup call to all of us."

I couldn't agree more. GAO's report is a call to action for both Congress and the Administration, warning us that our country must start thinking now about how to better prepare and adapt to a new climate reality. Today, our witness from GAO will further detail these financial risks to our communities and taxpayers and, hopefully, offer some common sense solutions that my colleagues and I can work with the Administration to see implemented.

Fortunately, this Administration, along with a number of state and local governments, are starting to focus their efforts on preparing for the very real threats posed by extreme weather events and climate change.

Last fall, President Obama issued an Executive Order on Climate Preparedness that incentivizes investments in more robust roads and buildings that may be more expensive, but can hold up during more intense storms.

I commend the President's approach and believe it is very timely as rebuilding efforts continue from Superstorm Sandy and other recent natural disasters.

I look forward to hearing more about the President's efforts and efforts by states like Delaware to do a better job protecting our communities and our taxpayer dollars from these challenges.

As we continue to debate how to reduce our deficits, I believe we can no longer afford to ignore the impacts these weather events are having on federal spending.

A little extra planning – combined with prudent, targeted investments – can go a long way in saving both lives and taxpayers dollars. I believe this is this is a perfect example of that very wise maxim -- an ounce of prevention is worth a pound of cure.

Thank you again to our witnesses for being here today. I am eager to hear your testimony.

With that I will turn it over to our acting Ranking Member, Senator McCain, for any thoughts he would like to offer.

Joint Statement for the Record

Assistant Secretary David Heyman Office of Policy Department of Homeland Security

And

Assistant Secretary Caitlin Durkovich
Office of Infrastructure Protection
National Protection and Programs Directorate
Department of Homeland Security

### "Extreme Weather Events: The Cost of Not Being Prepared"

Before the Committee on Homeland Security and Governmental Affairs United States Senate

### February 12, 2014

Thank you, Chairman Carper, Ranking Member Coburn, and distinguished Members of the Committee. It is a pleasure to appear before you today to discuss an issue of fundamental significance to the Department of Homeland Security and the Nation—resilience.

The Department of Homeland Security (DHS) is responsible for providing the coordinated, comprehensive federal response in the event of a terrorist attack, natural disaster or other large-scale emergency while working with federal, state, local, tribal, territorial and private sector partners to ensure a swift and effective recovery effort. This includes preparing for threats to critical infrastructure from extreme weather, often exacerbated by climate change, and responding to threats to critical infrastructure from extreme weather, often exacerbated by climate change, and other natural hazards.

Weather events present a significant and growing challenge, as evidenced by multiple multi-billion dollar disasters occurring in recent years. Trends such as the impacts of climate change, the vulnerability of aging infrastructure, and increasing population density in high-risk areas increase the risk of disasters. Natural disasters not only have the potential to cause severe consequences, including fatalities and economic loss, but also may overwhelm the capacities of critical infrastructure, causing widespread disruption of essential services across the country. Additionally, higher temperatures and more intense storms may damage or disrupt telecommunications and power systems, creating challenges for telecommunications infrastructure, emergency communications, and the availability of cyber systems.

### **Evolution of Resilience**

On May 26, 2009, President Obama announced his intent to combine the staffs supporting the Homeland Security Council and National Security Council into a single structure. Under this decision, President Obama decided that new organizational positions would be established within the National Security Council structure and he assigned responsibilities for resilience policy, including preparedness and response, to a new *Resilience Directorate*. The Resilience Directorate would lead the Domestic Resilience Group which would operate alongside the Counterterrorism Directorate and the Counterterrorism Security Group, putting security and resilience as the principal pillars of homeland security.

A year later, the Department of Homeland Security (DHS) published the Nation's first Quadrennial Homeland Security Review (QHSR)—a document that set the strategic direction of the nation in homeland security. In it, DHS defined *security* and *resilience* as the principal foundations of homeland security, mirroring the working arms of the National Security Staff (NSS). The Department also established "ensuring resilience to disasters" as one of its five primary missions.

The term 'resilience' had not been formally defined by the Federal government. In the March 2011 Presidential Policy Directive 8: National Preparedness (PPD-8), the Federal Government defined resilience as the "ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies." In practice, this means something much greater that affects Americans and is inherently tied to the security of our homeland. Resilience is the ability of citizens, businesses, and communities to: 1) proactively prepare for potential disasters so as to ensure that they are well-positioned to weather the impact; and 2) readily respond to a situation as it occurs to mitigate the threat or hazard.

In September 2011, the National Preparedness Goal (NPG) was published, which defines what it means for the United States to be prepared for all types of disasters and emergencies. Under the NPG, there are 31 core capabilities across prevention, protection, mitigation, response, and recovery mission areas. The NPG is followed by the National Planning Frameworks that describe the roles and responsibilities of everyone and how we come together to prevent, protect against, mitigate, respond, and recover from emergencies in order to ensure a secure and resilient Nation. Working with interagency partners, the Federal Emergency Management Agency (FEMA) PPD-8 Program Executive Office oversaw development of the Frameworks with state, local, tribal, territorial, and Federal partners and the private and non-profit sectors. In August 2013, FEMA released the Comprehensive Preparedness Guide 201, Second Edition, which provides communities with guidance for conducting a Threat and Hazard Identification and Risk Assessment (THIRA). The THIRA helps communities develop an understanding of trisks from natural, technological, and human-caused threats and hazards. In this way, communities can make informed decisions on how to manage risk and develop needed capabilities. Finally, DHS is shepherding with Federal partners the development of a National Campaign to Build and Sustain Preparedness. The initiative will ultimately four key elements: 1) a comprehensive campaign including public outreach, and community-based and private-sector programs;

2) federal preparedness efforts; 3) grants, technical assistance and other federal preparedness support; and 4) research and development.

As PPD-8 implementation evolved, the Administration heightened its focus on critical infrastructure security and resilience. While the policies and framework to build national preparedness and resilience are led by the Federal Government, the implementation and ability to be more prepared and resilient as a Nation, ultimately require partnerships and efforts across all of society—from individuals and first responders, to businesses, local governments and communities, all working together. And one year ago today, President Obama issued two policy documents which directly address the need for resilience in critical infrastructure. Presidential Policy Directive 21: Critical Infrastructure Security and Resilience (PPD-21) and Executive Order 13636, Improving Critical Infrastructure Cybersecurity, highlight the need to augment physical protective measures with additional emphasis on securing and strengthening the resilience of inter-related systems, PPD-21 directed DHS to develop an update to the National Infrastructure Protection Plan (NIPP), which was released in December 2013. The NIPP establishes the framework for integrating the various critical infrastructure security and resilience initiatives into a coordinated effort. The NIPP provides the structure through which DHS, in partnership with government and industry, implements programs and activities to protect critical infrastructure, promote national preparedness, and enhance incident response. The updated NIPP envisions a Nation in which physical and cyber critical infrastructure remain secure and resilient; essential services and products continue to be delivered in the face of incidents; and communities and businesses adapt to changing conditions and withstand and rapidly recover from potential disruptions.

### Why Resilience is Important to Homeland Security

The Nation's critical infrastructure provides the essential services that underpin the American way of life. A vast array of interdependent infrastructure and information technology networks, systems, services, and resources enable communication, facilitate travel, power our homes, run our economy, and provide essential government services. The aging or deteriorating condition of significant parts of these systems, however, both weaken our resilience and negatively affect our nation's security and prosperity. These challenges present significant obstacles to performing DHS's missions, particularly during times of disaster. The projected impacts of climate change, including sea level rise and increasing severity and frequency of extreme weather events, can cause damage or disruptions that result in cascading effects across our communities, with immeasurable costs in lives lost and billions of dollars in property damage.

Hurricane Sandy is a vivid example of the potentially devastating impacts extreme weather can have on critical infrastructure. The storm surge and associated flooding from Sandy caused widespread and catastrophic damage across New York, New Jersey, and surrounding areas, amassing approximately \$65 billion in damages. Communications, energy, transportation, healthcare, water, and wastewater systems were inoperable or

<sup>&</sup>lt;sup>1</sup> According to NOAA, the 2013 Consumer Price Index (CPI) cost adjusted value of Hurricane Sandy was \$65.7 billion. <a href="http://www.ncdc.noaa.gov/billions/events">http://www.ncdc.noaa.gov/billions/events</a>

severely degraded for weeks and months following the storm. The storm affected critical infrastructure in unprecedented and unexpected ways, demonstrating how interdependencies between infrastructure systems can magnify impacts and delay restoration, and underscoring how pre-planning, coordination, and improved design and construction approaches can ease effects.

Additionally, the increasingly integral role of cyber and communications networks creates new vulnerabilities and opportunities for disruption. Communications and information technology networks enable automated switching and distribution SCADA (supervisory control and data acquisition) systems in order to provide utilities with enhanced capabilities for remote monitoring and the ability to proactively address outages. Two years ago, high temperatures and high demand tripped a transformer and transmission line in Yuma, AZ, starting a chain of events that shut down the San Onofre nuclear power plant, leading to a large-scale power outage across the entire San Diego distribution system. While strides have been made to address the vulnerabilities that led to such outages, additional progress is needed to secure our interrelated systems in the face of varied threats.

### **DHS Resilience Operations**

Establishing resilience in doctrine, while important, is separate from the task of establishing resilience in daily operations. FEMA, the National Protection and Programs Directorate (NPPD), Science & Technology Directorate (S&T), Office of Health Affairs (OHA), and the Office of Policy (PLCY)—are the DHS components most heavily involved in the development or execution of programs to build national resilience. In FY 2013, the Department allocated approximately \$16.1 billion for programs and activities with a nexus to the Resilience Mission.

## Role of NPPD

DHS supports private sector owners and operators of critical infrastructure in preparing for, preventing, protecting against, mitigating, responding to, and recovering from incidents that affect their infrastructure. NPPD is responsible for leading and coordinating the national effort to protect critical infrastructure from all hazards by managing risk and enhancing resilience through collaboration with the critical infrastructure community. To achieve this end, NPPD's Office of Infrastructure Protection (IP) works with public and private sector partners to identify and promote effective solutions for security and resilience to manage the evolving risk environment.

Because the majority of the Nation's infrastructure is owned and operated by the private sector, NPPD works with owners and operators, primarily on a voluntary basis, to understand evolving threats, share information on these threats and hazards, and promote best practices, training, and tools to help mitigate risks. By leveraging its core capabilities, such as information and data sharing, capacity development, vulnerability assessments, and situational awareness, NPPD is effectively using its skills and resources to assist with building the Nation's resilience to extreme weather and cybersecurity risks.

As a part of the Hurricane Sandy Rebuilding Taskforce, NPPD-IP and other Federal partners worked to develop the Infrastructure Resilience Guidelines, which are sound investment principles to guide Federal infrastructure investment following a disaster. Included in the Guidelines is the concept that certain core approaches—incorporating changing climate and development patterns, making risk-based decisions, and evaluating approaches and techniques throughout the project lifecycle—will help encourage investment in more resilient infrastructure.

Additionally, IP co-chairs the new Infrastructure Resilience Work Group with the Department of Energy under the White House-led Council on Climate Preparedness and Resilience. The purpose of this working group is to develop, recommend, and coordinate interagency efforts on climate preparedness and resilience for the Nation's infrastructure, and to track implementation of interagency actions, including those in the President's Climate Action Plan and Executive Order 13653, "Preparing the United States for the Impacts of Climate Change." IP's responsibilities include leading an effort to study infrastructure most vulnerable to climate impacts throughout the United States and identifying risk-based hazard mitigation and adaptation strategies. This will inform and aid the critical infrastructure community with planning and decision making regarding climate preparedness and resilience.

Furthermore, IP's Regional Resiliency Assessment Program (RRAP) examines a particular industry, region, or municipality's dependence on key lifeline sectors and the hazards and vulnerabilities that can affect the functioning of the complex systems of infrastructure that underpin the selected region's communities. RRAPs already collect data regarding natural hazard risks to infrastructure assets. Each year, IP conducts a series of RRAPs focused on different topics and has created a comprehensive library of actions that owners, operators, and state, local, tribal, and territorial partners can take to prevent an incident from occurring and mitigate consequences from any incident that does occur.

### Role of FEMA

FEMA is often the Department lead and public face of resilience initiatives, leading implementation of National Preparedness (PPD-8) on behalf of DHS and the Nation. PPD-8 aims to strengthen the security and resilience of the United States through the systematic preparation for the threats and hazards that pose the greatest risk to the Nation. It also focuses on an integrated all-of-Nation, capabilities-based approach to preparedness—including all levels of government, private and nonprofit sectors, faith-based organizations, communities, and individuals.

Operationally, FEMA takes a *Whole Community* approach to emergency management. A Whole Community approach is based on the notion that FEMA is only one part of our nation's emergency management team; that we must leverage all of the resources of our collective team in preparing for, protecting against, responding to, recovering from and mitigating against all hazards; and that collectively we must meet the needs of the entire community in each of these areas. This larger collective emergency management team includes not only FEMA and its partners at the federal level, but also local, tribal, state and territorial partners; non-governmental organizations like faith-based and non-profit

groups and private sector industry; and individuals, families and communities, who continue to be the Nation's most important assets as first responders during a disaster. Both the composition of the community and the individual needs of community members, including factors such as age, economics, and accessibility requirements, must be accounted for when planning and implementing disaster strategies.

FEMA helps build community resilience through its grants to state local, tribal, and territorial governments, urban areas, the private sector and non-profit agencies. Since 2002, more than \$38 billion in preparedness grant funding has been awarded to Whole Community partners. FEMA funding supported the development and training of the New York City Fire Department's Incident Management Team, which was activated to support Hurricane Sandy to help manage homebound evacuations, provide for fire and life safety, and manage tree removal and dewatering operations. FEMA also funded Oklahoma Task Force One, which conducted search and rescue operations at two schools, as well as businesses and homes, following the tornado in Moore, Oklahoma in May 2013. Additionally, FEMA, in partnership with the Rockefeller Foundation, created the Community Resilience Innovation Challenge to build local resilience in communities across the United States; FEMA announced 30 grant recipients for this program in May 2013, with applications open to state, local, tribal, and territorial governments, businesses, associations, and community groups.

Internationally, FEMA established the Multinational Resilience Policy Group—a partnership of Australia, Canada, Italy, Germany, the Netherlands, New Zealand, Singapore, Sweden, the United Kingdom, and the United States to identify, collect, analyze, and share policy insights from countries' respective experiences and perspectives.

Over the next several years, DHS, working with the National Academies, will convene a roundtable of experts from the academic, public, and private sectors to design or catalyze activities that build resilience to extreme events. The roundtable will provide the venue for current research, science, and evidence-based foundations to inform whole community strategies for building resilience.

FEMA is making great progress in building national preparedness and resilience. However, one FEMA tool—the National Flood Insurance Program (NFIP), which provides flood insurance protection to property owners in exchange for local government floodplain management activities—is in debt \$24 billion. This is due to spiraling costs and increasing payouts, particularly as events are becoming more extreme. This underscores the fiscal impact that severe weather is having on the U.S. According to the U.S. Global Change Research Program, future impacts of climate change project national economic losses on the order of \$1.2 trillion through 2050.

Role of the Science and Technology Directorate

S&T is the primary research and development arm of the Department. S&T's Resilient Systems Division develops technology capabilities to enhance the Nation's resilience in the face of evolving risks with increasingly costly impacts such as natural disasters as well as industrial accidents in the cyber and physical arenas. For example, S&T's Resilient

Electrical Grid project is developing new solutions to ensure reliability and availability of services in times of disaster. S&T has also developed a set of modeling and simulation solutions to enable rapid assessment of the implications of natural hazards for planning, response, and recovery operations. These solutions provide a unique capability that will help the Department understand the impacts of climate change on critical infrastructure, so hazard mitigation strategies can be planned and implemented in both the short and long term

Since December of 2010, S&T has facilitated the Virtual Social Media Working Group (VSMWG), a working group comprised of several local, state, federal, academic, and non-profit stakeholders. The VSMWG meets monthly to discuss various challenges and engages with the public safety community on an ongoing basis to develop and provide assistance, and guidance to the emergency preparedness and response community on the safe and sustainable use of social media technologies before, during, and after emergencies. In July of 2013, the VSMWG published Lessons Learned: Social Media and Hurricane Sandy², a landscape analysis of how social media was used in preparation for, in response to, and in recovery from Hurricane Sandy in October of 2012. The report, which includes discussion and examples of various processes, themes in application, lessons learned, and identifies gaps in technology, process, and policy requiring further discussion, has been shared as an essential resource across the public safety community; it helps to inform future development of new technologies and processes necessary to achieve and maintain resilience against future events.

### Role of the Office of Health Affairs

OHA coordinates all medical activities within the Department to ensure appropriate preparation for and response to incidents. OHA also serves as the principal advisor to the Secretary and FEMA Administrator on medical and public health issues. OHA's Community Health Resilience Initiative is a partnership of public and private partners to strengthen resilience-related health initiatives across the Nation. A web-based toolset is currently in development and will provide planning guidance for communities to improve health resilience. OHA works closely with our Health and Human Services (HHS) partners to ensure integration of health resilience activities. The initiative incorporates climate change considerations.

### Role of DHS Office of Policy

DHS PLCY facilitates the coordination of resilience activities across the Department, while assessing and incubating efforts that will help strengthen the execution of the Resilience Mission and our Nation's ability to withstand disasters. In 2010, PLCY established and currently leads the Department's Resilience Integration Team (RIT)—a team of resilience experts from across DHS components. The RIT was formed for the principal purpose of

<sup>&</sup>lt;sup>2</sup> DHS Science and Technology Directorate, First Responders Group, Virtual Social Media Working Group (VSMWG). Lessons Learned: Social Media and Hurricane Sandy; June, 2013. https://communities.firstresponder.gov/DHS\_VSMWG\_Lessons\_Learned\_Social\_Media\_and\_Hurricane\_Sandy\_Formatted\_June\_2013\_FINAL.pdf, accessed February 6, 2014.

turning resilience concepts into action, following the publication of the 2010 QHSR and establishment of Resilience as a key homeland security mission.

Through the RIT, the Department has developed and launched two key Departmental resilience initiatives: *the Rick Rescorla National Award for Resilience* and the Resilience STAR™ Home Pilot.

- The Rick Rescorla National Award for Resilience, named after fallen 9/11 hero Rick
  Rescorla, recognizes local and national leadership in preparedness and resilience by
  organizations and individuals, as a means of both catalyzing and inspiring a culture of
  resilience across America. The 2013 recipients, announced this past December, were
  recognized for exemplary activities of leadership with respect to preparedness,
  response, and recovery in the face of one of the Nation's most devastating storms,
  Hurricane Sandy.
- Resilience STAR™, modeled after the Environmental Protection Agency's successful ENERGY STAR™ program is a partnership between DHS and the Insurance Institute for Business and Home Safety to designate homes that are built to "code-plus" standards as "Resilience STAR compliant." Homes built to these standards will incur significantly less property damage caused by natural disasters, protecting lives, livelihoods, and a community's ability to withstand and recover from disasters. Resilience STAR™ seeks to identify the business case and return on investment for building resilient homes in order to encourage consumers and businesses to consider the benefits of building resilience into the construction (or retrofitting) of their homes. Ultimately, DHS aims to extend Resilience STAR™ beyond homes and facilities, and into critical infrastructure, helping to recapitalize the built environment across America in the long term, one home, one building and one bridge or critical asset at a time.

These initiatives serve as key tools that the Department may use to incentivize and encourage individuals and communities to build resilience concepts into their lives and business practices.

Further, PLCY leads the "One DHS" effort on climate adaptation – a Departmental initiative to ensure DHS missions appropriately account for climate risk as well as programs for key external stakeholders. In September 2013, then-Secretary Napolitano signed the DHS Climate Action Plan, which aligns to and implements the vision of The President's Climate Action Plan. PLCY chairs both the executive-level and program manager-level bodies that regularly meet to ensure implementation. There are 36 actions in all, intended to help state and local governments, private sector owners and operators of infrastructure and individuals across the U.S. be climate prepared.

### Mitigating Costs through Infrastructure Resilience

The U.S. Government can neither predict nor protect against all threats or hazards. And we know that the benefits of investing in resilience, such as building and design, for example, are significant. In 2005, the Multi-hazard Mitigation Council conducted an independent, congressionally-mandated study that determined that for every federal dollar spent on

mitigation, American society saves an average of four dollars post-disaster.<sup>3</sup> This figure is likely multiplied when factoring in state, local, territorial, and tribal government, private sector, and individual investments.

With changing climate and development patterns and the severity and frequency of extreme weather events increasing, the U.S. cannot afford to leave homes, communities, and critical infrastructure vulnerable. There was a record 98 Presidentially-declared disasters in FY 2011 alone. According to Munich Re, the world's largest risk reinsurer, weather related catastrophes struck North America hardest from 1980-2010 compared to the rest of the world. Total economic losses to the United States were approximately \$1.15 trillion during that period.<sup>4</sup> Without a concerted national resilience effort, the trend is likely to continue. Intergovernmental agencies and the scientific community, such as the Intergovernmental Panel on Climate Change and the U.S. Global Change Research Program, warn that extreme weather may occur with increasing frequency. The effort must be national as extreme weather events take on many forms affecting various regions of the country. This includes: massive flooding, excessively high temperatures, an increase in wildfires, more severe downpours and conversely more severe droughts, increased storm surge and sea-level rise.

Infrastructure built now can have a design life span of 50 years or more, and will be expected to operate under future stressor conditions, whatever they may be. As a result, it is a prudent investment to incorporate resilience into asset and system design and promote hazard mitigation in built infrastructure, rather than rebuild or redesign infrastructure after incidents occur.

To achieve infrastructure resilience, owners and operators along with government and nongovernmental partners must be able to maintain essential services provided by critical infrastructure to our communities regardless of the hazard or threat, and when a disruption occurs, ensure essential services and functions are brought back to full operations as quickly as possible. To accomplish this, DHS is leveraging a whole community, all-hazards approach to better prepare for, protect against, mitigate, respond, and recover from extreme weather.

# A Shared Responsibility: The Importance of Community and Individual Resilience and Preparedness

The Department also recognizes the importance of building national resilience from the ground up. Building resilience is not simply about government action alone, but rather about the collective strength of this entire country. That effort and that strength begins with individuals—private citizens taking the initiative to be prepared.

Civilians are usually the first to arrive in a crisis, and history shows that they are critical in those important first minutes. In order to maximize their ability to help themselves, their

<sup>&</sup>lt;sup>3</sup> Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities (2005). http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/MMC/hms\_vol1.pdf

<sup>&</sup>lt;sup>4</sup> See generally The Munich Re Report, summary available at http://www.munichre.com/en/media relations/press releases/2012/2012 10 17 press release.aspx.

communities, and the U.S. Government respond to and mitigate threats, we must ensure that they are well-equipped and understand the importance of preparing for and responding to disasters. Citizen responders have the capacity to act as force multipliers and can be an even more potent force if they know what steps they can take to prepare.

America's PrepareAthon! is a nationwide, community-based campaign for action to increase emergency preparedness and resilience. Twice yearly, in the spring and fall, America's PrepareAthon! will provide a national focus for individuals, organizations and communities to participate through drills, group discussions and exercises to practice for local hazards

The Department's **Ready.gov** website serves as a resource for citizens, outlining ways that citizens can stay informed, make appropriate plans, build kits, and get involved in their communities. Some of these steps include:

- Taking CPR training and joining or initiating community planning and response teams;
- Training with a Community Emergency Response Team to learn basic disaster response skills to employ when professional responders are not immediately available; skills include: fire safety, light search and rescue, disaster medical operations, and team organization;
- Understanding under what circumstances they should take shelter or evacuate;
- Assembling an emergency "go kit" to take during an evacuation and what emergency supplies to maintain at home to be able to shelter-in-place without outside assistance for at least three days;
- Pre-planning evacuation routes and where to meet family after a disaster strikes.

By taking these simple steps, citizens are not only prepared should disaster strike, but their actions also enable first responders and emergency personnel to focus on those most in need

One of our closest federal partners – the National Oceanic and Atmospheric Administration (NOAA) – has set a strategic goal to build a "Weather-Ready Nation" to increase the resilience of the American people in the face of growing exposure to dangerous weather and water events. Over the past two years, this strategic goal has grown into a campaign that involves both the public and private sectors.

In the end, resilience is a shared responsibility that requires individual citizens, communities, and government to take critical steps to be prepared when disaster strikes, and to work together to ensure we are well-equipped to withstand whatever threats and hazards we may face. It is imperative that DHS do everything we can to ensure that individuals, businesses, and communities understand their responsibility to prepare themselves, have the tools at their disposal to do so, and understand the impact they can have on their community. It is in the actions of each of us, that we ensure the safety and security of all of us.

## Closing

The Department of Homeland Security is committed to the important mission of resilience. By encouraging a culture and practice of resilience among citizens, and by building resilience into homes, communities, and critical infrastructure, we can better protect the lives and livelihoods of Americans, while ensuring that the costs associated with disaster recovery are markedly diminished.

Thank you for the opportunity to appear before this Committee. We look forward to answering any questions you may have.



**United States Government Accountability Office** 

Testimony
Before the Committee on Homeland
Security and Governmental Affairs,
U.S. Senate

For Release on Delivery Expected at 10:00 a.m. EST Wednesday, February 12, 2014

# EXTREME WEATHER EVENTS

Limiting Federal Fiscal Exposure and Increasing the Nation's Resilience

Statement of Mark Gaffigan, Managing Director Natural Resources and Environment

# GAO Highlights

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#### February 12, 2014

### **EXTREME WEATHER EVENTS**

## Limiting Federal Fiscal Exposure and Increasing the Nation's Resilience

### What GAO Found

The federal government has opportunities to limit its exposure and increase the nation's resilience to extreme weather events. Since 1980, the U.S. has experienced 151 weather disasters with damages exceeding 1 billion dollars each. This testimony focuses on 4 areas where the government could limit its fiscal exposure.

- Property and crop insurance. The financial risks from two federal insurance programs—the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA) and the Federal Crop Insurance Corporation (FCIC)—create a significant fiscal exposure. In 2012, the NFIP had property coverage of over \$1.2 trillion and the FCIC had crop coverage of almost \$120 billion. As of December 2013, FEMA's debt from flood insurance payments totaled about \$24 billion. For various reasons, FCIC's costs more than doubled from \$3.4 billion in fiscal year 2001 to \$7.6 billion in fiscal year 2012. In 2007, GAO found that the agencies responsible for these programs needed to develop information on their long-term exposure to climate change. The Biggert-Waters Flood Insurance Reform Act of 2012 requires FEMA to use information on future changes in sea levels and other factors in updating flood maps used to set insurance rates. Private insurers are also studying how to include climate change in rate setting. GAO is currently examining the extent to which private and federal insurance programs address risks from climate change.
- <u>Disaster aid.</u> The federal government does not fully budget for recovery
  activities after major disasters, thus creating a large fiscal exposure. GAO
  reported in 2012 that disaster declarations have increased to a record 98 in
  fiscal year 2011 compared with 65 in 2004. Over that period, FEMA obligated
  over \$80 billion for disaster aid. GAO's past work recommended that FEMA
  address the federal fiscal exposure from disaster assistance.
- Owner and operator of infrastructure. The federal government owns and operates hundreds of thousands of facilities that a changing climate could affect. For example, in its 2010 Quadrennial Defense Review, the Department of Defense (DOD) recognized the risk to its facilities posed by climate change, noting that the department must assess the potential impacts and adapt. GAO plans to report later this year on DOD's management of climate change risks at over 500,000 defense facilities.
- Provider of technical assistance to state and local governments. The federal government invests billions of dollars annually in infrastructure projects that state and local governments prioritize, such as roads and bridges. Total public spending on transportation and water infrastructure exceeds \$300 billion annually, with about 25 percent coming from the federal government and the rest from state and local governments. GAO's April 2013 report on infrastructure adaptation concluded that the federal government could help state and local efforts to increase their resilience by (1) improving access to and use of available climate-related information, (2) providing officials with improved access to local assistance, and (3) helping officials consider climate change in their planning processes.

United States Government Accountability Office

Chairman Carper, Ranking Member Coburn, and Members of the Committee:

Thank you for inviting me to discuss our work on opportunities for the federal government to reduce the fiscal exposure and financial risks posed by extreme weather events.¹ According to the United States Global Change Research Program (USGCRP), the impacts and costliness of weather disasters—resulting from floods, drought, and other events such as tropical cyclones—are expected to increase in significance as previously "rare" events become more common and intense due to anticipated changes in the global climate system.² Typically, climate change is described as average annual changes in temperature or precipitation, and is associated with shifts in the frequency and severity of extreme weather that can impose substantial costs on society. The 151 weather disasters since 1980 with overall damages exceeding \$1 billion each illustrate these vulnerabilities.³ While it is not possible to link any individual weather event to climate change, these events provide insight into the potential climate-related vulnerabilities the United States faces.

Our past work identified a variety of fiscal exposures—responsibilities, programs, and activities that may either legally commit the federal government to future spending or create the expectation for future spending. Fiscal exposures vary widely as to source, extent of the government's legal commitment, and magnitude. Further, some of these factors may change over time. For example, the government's response to an event or series of events can strengthen expectations that the government will respond in the same way to similar events in the future. For additional information, see *Fiscal Exposures: Improving Cost Recognition in the Federal Budget*, GAO-14-28 (Washington, D.C.: Oct. 29, 2013).

27. Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds. Global Climate Change Impacts in the United States (Cambridge University Press: 2009). USGCRP coordinates and integrates the activities of 13 federal agencies that conduct research on changes in the global environment and their implications for society. USGCRP began as a presidential initiative in 1989 and was codified in the Global Change Research Act of 1990 [Pub. L. No. 101-606, § 103 (1990)]. USGCRP-participating agencies are the Departments of Agriculture, Commerce, Defense, Energy, Interior, Health and Human Services, State, and Transportation, U.S. Agency for International Development, Environmental Protection Agency; National Aeronautics and Space Administration; the National Science Foundation; and the Smithsonian Institution.

<sup>3</sup>The National Oceanic and Atmospheric Administration's National Climatic Data Center tracks and evaluates climate events in the United States and globally that have great economic and societal impacts. Additional information on billion dollar weather disasters is available here.

Federal, state, and local policymakers increasingly view adaptation—adjustments to natural or human systems in response to actual or expected climate change—as a risk-management strategy to protect vulnerable sectors and communities that could be affected by extreme weather events and changes in the climate. For example, adaptation measures may include raising river or coastal dikes to protect infrastructure from sea level rise, building higher bridges, and increasing the capacity of storm water systems. As stated in a 2010 National Research Council (NRC) report, even though uncertainties exist regarding the exact nature and magnitude of impacts, mobilizing now to increase the nation's resilience can be an insurance policy against climate change risks.<sup>4</sup>

My testimony today is based on reports we issued from March 2007 to November 2013. We conducted work for these reports in accordance with generally accepted government auditing standards. Our issued reports have detailed information about our scope and methodology.

Limiting Federal Fiscal Exposure and Financial Risks from Extreme Weather Events by Increasing the Nation's Resilience Among other impacts, climate change could threaten coastal areas with rising sea levels, alter agricultural productivity, and increase the intensity and frequency of severe weather events such as floods, drought, and hurricanes that have cost the nation tens of billions of dollars in damages over the past decade. For example, Congress provided around \$60 billion in budget authority for disaster assistance after Superstorm Sandy. These impacts pose significant financial risks, but the federal government is not well positioned to address this fiscal exposure, partly because of the complex nature of the issue. Given these challenges and the nation's fiscal condition, in February 2013, we added *Limiting the Federal* 

<sup>&</sup>lt;sup>4</sup>NRC, America's Climate Choices: Panel on Adapting to the Impacts of Climate Change, Adapting to the Impacts of Climate Change (Washington, D.C.: 2010). NRC is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering.

<sup>&</sup>lt;sup>5</sup>Congress temporarily increased the borrowing authority for the National Flood Insurance Program by \$9.7 billion and provided about \$50 billion in appropriated funds for expenses related to the consequences of Superstorm Sandy.

Government's Fiscal Exposure by Better Managing Climate Change Risks to our list of high-risk areas.<sup>6</sup>

Climate-related impacts will result in increased fiscal exposures for the federal government from many areas, including, but not limited to its role as (1) the insurer of property and crops vulnerable to climate impacts, (2) the provider of aid in response to disasters, (3) the owner or operator of extensive infrastructure such as defense facilities and federal property vulnerable to climate impacts, and (4) the provider of data and technical assistance to state and local governments responsible for managing the impacts of climate change on their activities.

### Federal Government as Insurer of Property and Crops

The financial risks from two important federal insurance programs—the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA) and the Federal Crop Insurance Corporation (FCIC) administered by the United States Department of Agriculture (USDA)—create a significant fiscal exposure. In 2012, the NFIP had property coverage of over \$1.2 trillion and the FCIC had crop coverage of almost \$120 billion. NFIP has been on our High Risk List since March 2006 because of concerns about its long-term financial solvency and related operational issues. While Congress and FEMA intended to finance NFIP with premiums collected from policyholders and not with tax dollars, the program was, by design, not intended to pay for itself. As of December 2013, FEMA's debt from flood insurance payments totaled about \$24 billion—up from \$17.8 billion before Superstorm Sandy—and FEMA had not repaid any principal on the loan since 2010.7 Further, the federal government's crop insurance

<sup>&</sup>lt;sup>6</sup>GAO, *High-Risk Series: An Update*, GAO-13-283, February 2013. Every 2 years at the start of a new Congress, GAO calls attention to agencies and program areas that are high risk due to their vulnerabilities to fraud, waste, abuse, and mismanagement, or are most in need of transformation. Click here to access the *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* content. The focus of this high-risk area may evolve over time to the extent that federal climate change programs and policies change.

<sup>&</sup>lt;sup>7</sup>FEMA has authority to borrow money from Treasury to pay losses that exceed premium revenue and any accumulated surplus. Treasury charges FEMA interest on the outstanding debt. Before Superstorm Sandy, this borrowing authority stood at \$20.725 billion. In January 2013, Congress passed and the President signed into law a \$9.7 billion increase in this authority to pay flood claims related to Superstorm Sandy, raising FEMA's borrowing authority to a total of \$30.425 billion. Pub. L. No. 113-1, § 1(a), 127 Stat. 3, 3 (2013).

costs have increased in recent years for a variety of reasons, more than doubling from \$3.4 billion in fiscal year 2001 to \$7.6 billion in fiscal year 2012.8

In March 2007, we reported that both of these programs' exposure to weather-related losses had grown substantially, and that FEMA and USDA had done little to develop the information necessary to understand their long-term exposure resulting from climate change. <sup>9</sup> We recommended that the Secretaries of Agriculture and Homeland Security analyze the potential long-term fiscal implications of climate change on federal insurance programs and report their findings to Congress. The agencies agreed with the recommendation and contracted with experts to study their programs' long-term exposure from climate change. Both agencies have incorporated the findings of the reports into their climate change adaptation plans—as directed by instructions and guidance implementing Executive Order 13514 on Federal Leadership in Environmental, Energy, and Economic Performance. We are currently examining how these programs account for climate change in their activities.

In addition, we have previously reported on external factors that complicate the administration of NFIP and affect its financial stability. <sup>10</sup> In June 2011, we reported that FEMA had not been authorized to account for long-term erosion when updating flood maps used to set premium rates for NFIP, increasing the likelihood that premiums would not cover future losses. We therefore suggested that Congress consider authorizing NFIP to account for long-term erosion in its flood maps. <sup>11</sup> Subsequently, Congress passed the Biggert-Waters Flood Insurance Reform Act of 2012 (Biggert-Waters Act), which requires FEMA to use information on

<sup>&</sup>lt;sup>B</sup>GAO-14-28.

<sup>&</sup>lt;sup>9</sup>GAO, Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades Are Potentially Significant, GAO-07-285 (Washington, D.C.: Mar. 16, 2007).

<sup>&</sup>lt;sup>10</sup>GAO, National Flood Insurance Program: Continued Attention Needed to Address Challenges, GAO-13-858T (Washington, D.C.: Sept. 18, 2013), GAO, Flood Insurance: Implications of Changing Coverage Limits and Expanding Coverage, GAO-13-568 (Washington, D.C.: July 3, 2013).

<sup>&</sup>lt;sup>11</sup>GAO, FEMA: Action Needed to Improve Administration of the National Flood Insurance Program, GAO-11-297 (Washington, D.C.; June 9, 2011).

topography, coastal erosion areas, changing lake levels, future changes in sea levels, and intensity of hurricanes in updating its flood maps. 12

The Biggert-Waters Act also reauthorized NFIP through 2017 and made other significant changes to the program, including removing subsidized premium rates for certain properties, eliminating the grandfathering of prior premium rates when a property is remapped, and requiring FEMA to create a reserve fund. While these changes may help put NFIP on a path to financial solvency, their ultimate effect is not yet known. In addition, the program faces challenges in making the changes. For example, implementation of certain changes was delayed by provisions in the Consolidated Appropriations Act of 2014, and S. 1926, which passed the Senate on January 30, 2014, would delay the implementation of certain rate increases contained in the Biggert-Waters Act. As we have previously reported, such delays to rate increases may help address affordability concerns, but they would likely continue to increase NFIP's long-term burden on taxpayers. <sup>13</sup>

### Federal Government as Provider of Disaster Aid

In the event of a major disaster, federal funding for response and recovery comes from the Disaster Relief Fund managed by FEMA, and disaster aid programs of other participating federal agencies. <sup>14</sup> The federal government does not fully budget for these costs, thus creating a

 $<sup>^{12}\</sup>text{Pub. L.}$  No 112-141, Div. F, Tit. II, Subtit. A, § 100216(b), 126 Stat. 405, 927 (2012) (codified at 42 U.S.C. 4101b(b)).

<sup>&</sup>lt;sup>13</sup>GAO, Flood Insurance: Strategies for Increasing Private Sector Involvement, GAO-14-127 (Washington, D.C.: Jan. 22, 2014).

GAO-14-127 (Washington, D.C.: Jan. 22, 2014).

14As reported by the Congressional Research Service in August 2013, Congress appropriates money to the Disaster Relief Fund to ensure that funding for disaster relief is available to help individuals and communities stricken by emergencies and major disasters. Congress also appropriates disaster funds to other accounts administered by other federal agencies pursuant to federal statutes that authorize specific types of disaster relief. The Disaster Relief Fund is generally funded at a level that is sufficient for what are known as "normal" disasters. These are incidents for which Disaster Relief Fund outlays are less than \$500 million. When a large disaster occurs, additional funding for the Disaster Relief Fund may be provided through emergency supplemental appropriations. A supplemental appropriation generally provides additional budget authority during the current fiscal year to (1) finance activities not provided for in the regular appropriation or (2) provide funds when the regular appropriation is deemed insufficient. For more information, see Congressional Research Service, Disaster Relief Funding and Supplemental Appropriations for Disaster Relief, R40708, (Washington, D.C.: Aug. 5, 2013).

large fiscal exposure. We reported, in September 2012, that disaster declarations have increased over recent decades to a record of 98 in fiscal year 2011 compared with 65 in 2004. To Over that period, FEMA obligated over \$80 billion in federal assistance for disasters. We also found that FEMA has had difficulty implementing long-standing plans to assess national preparedness capabilities and that FEMA's indicator for determining whether to recommend that a jurisdiction receive disaster assistance does not accurately reflect the ability of state and local governments to respond to disasters. Had FEMA adjusted its indicator to reflect changes in personal income and inflation, 44 percent and 25 percent fewer disaster declarations, respectively, would have met the threshold for public assistance during fiscal years 2004 through 2011. In September 2012, we recommended, among other things, that FEMA develop a methodology to more accurately assess a jurisdiction's capability to respond to and recover from a disaster without federal assistance. FEMA concurred with this recommendation.

### Federal Government as Property Owner and Operator

The federal government owns and operates hundreds of thousands of buildings and facilities that a changing climate could affect. For example, in its 2010 Quadrennial Defense Review, the Department of Defense (DOD) recognized the risk to its facilities posed by climate change, noting that the department must assess potential impacts and adapt as required. We plan to report later this year on DOD's management of climate change risks at over 500,000 defense facilities. In addition, the federal government manages about 650 million acres—nearly 30 percent of the land in the United States—for a variety of purposes, such as recreation, grazing, timber, and fish and wildlife. In 2007, we recommended that the Secretaries of Agriculture, Commerce, and the Interior develop guidance for their resource managers that explains how they expect to address the effects of climate change, and the three

<sup>&</sup>lt;sup>15</sup>GAO, Federal Disaster Assistance: Improved Criteria Needed to Assess a Jurisdiction's Capability to Respond and Recover on Its Own, GAO-12-838 (Washington, D.C.: Sept. 12, 2012).

<sup>&</sup>lt;sup>16</sup>GAO, Managing Preparedness Grants and Assessing National Capabilities, GAO-12-526T (Washington, D.C.: Mar. 20, 2012). See also GAO, Disaster Response: Criteria for Developing and Validating Effective Response Plans, GAO-10-969T (Washington, D.C.: Sept. 22, 2010).

<sup>&</sup>lt;sup>17</sup>The Quadrennial Defense Review is a legislatively mandated review of DOD strategies and priorities and is required to be conducted every 4 years.

departments generally agreed with this recommendation. <sup>18</sup> However, as we showed in our May 2013 report, resource managers still struggled to incorporate climate-related information into their day-to-day activities, despite the creation of strategic policy documents and high-level agency guidance. <sup>19</sup>

### Federal Government as Provider of Technical Assistance to State and Local Governments

The federal government invests billions of dollars annually in infrastructure projects that state and local governments prioritize and supervise. In total, the United States has about 4 million miles of roads and 30,000 wastewater treatment and collection facilities. According to a 2010 Congressional Budget Office report, total public spending on transportation and water infrastructure exceeds \$300 billion annually, with roughly 25 percent of this amount coming from the federal government and the rest coming from state and local governments. <sup>20</sup> These projects have large up-front capital investments and long lead times that require decisions about addressing climate change before its potential effects are discernable. The federal government plays a limited role in project-level planning for transportation and wastewater infrastructure, and state and local efforts to consider climate change in infrastructure planning have occurred primarily on a limited, ad hoc basis.

Infrastructure is typically designed to withstand and operate within historical climate patterns. However, according to NRC, as the climate changes and historical patterns—in particular, those related to extreme weather events—no longer provide reliable predictions of the future, infrastructure designs may underestimate the climate-related impacts to infrastructure over its design life, which can range as long as 50 to 100 years.<sup>21</sup> These impacts can increase the operating and maintenance

<sup>&</sup>lt;sup>18</sup>GAO, Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources, GAO-07-863 (Washington, D.C.: Aug. 7, 2007).

<sup>&</sup>lt;sup>19</sup>GAO, Climate Change: Various Adaptation Efforts Are Under Way at Key Natural Resource Management Agencies, GAO-13-253 (Washington, D.C.: May 31, 2013).

<sup>&</sup>lt;sup>20</sup>Congressional Budget Office, Public Spending on Transportation and Water Infrastructure, Pub. No. 4088 (Washington, D.C.: November 2010).

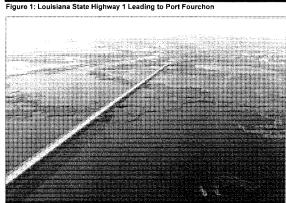
<sup>&</sup>lt;sup>21</sup>See, for example, NRC, Panel on Strategies and Methods for Climate-Related Decision Support, Committee on the Human Dimensions of Global Change, *Informing Decisions in a Changing Climate* (Washington, D.C.: 2009).

costs of infrastructure or decrease its life span, or both, leading to social, economic, and environmental impacts.

For example, the National Oceanic and Atmospheric Administration estimates that, within 15 years, segments of Louisiana State Highway 1—the only road access to Port Fourchon, which services virtually all deepsea oil operations in the Gulf of Mexico, or about 18 percent of the nation's oil supply—will be inundated by tides an average of 30 times annually due to relative sea level rise. Flooding of this road effectively closes this port. Because of Port Fourchon's significance to the oil industry at the national, state, and local levels, the U.S. Department of Homeland Security, in July 2011, estimated that a closure of 90 days could reduce the national gross domestic product by \$7.8 billion.<sup>22</sup> Figure 1 shows Louisiana State Highway 1 leading to Port Fourchon.

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<sup>&</sup>lt;sup>22</sup>Department of Homeland Security, National Infrastructure Simulation and Analysis Center, Risk Development and Modeling Branch, Homeland Infrastructure Threat and Risk Analysis Center, Office of Infrastructure Protection, In Collaboration with the National Incident Management Systems and Advanced Technologies Institute at the University of Louisiana at Lafayette, Louisiana Highway 1/Port Fourchon Study (July 15, 2011).



Despite the risks posed by climate change, we found, in April 2013, that infrastructure decision makers have not systematically incorporated potential climate change impacts in planning for roads, bridges, and potential climate change impacts in pianning for roads, prieges, and wastewater management systems because, among other factors, they face challenges identifying and obtaining available climate change information best suited for their projects. <sup>23</sup> Even where good scientific information is available, it may not be in the actionable, practical form needed for decision makers to use in planning and designing infrastructure. Such decision makers work with traditional engineering processes, which often require very specific and discrete information. Moreover, local decision makers—who, in this case, specialize in infrastructure planning, not climate science—need assistance from experts who can help them translate available climate change information into something that is locally relevant. In our site visits to a limited number

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<sup>&</sup>lt;sup>23</sup>GAO, Climate Change: Future Federal Adaptation Efforts Could Better Support Local Infrastructure Decision Makers, GAO-13-242 (Washington, D.C.: Apr. 12, 2013).

of locations where decision makers overcame these challenges—including Louisiana State Highway 1—state and local officials emphasized the role that the federal government could play in helping to increase their resilience.<sup>24</sup>

Any effective adaptation strategy must recognize that state and local governments are on the front lines in both responding to immediate weather-related disasters and in preparing for the potential longer-term impacts associated with climate change. We reported, in October 2009, that insufficient site-specific data—such as local temperature and precipitation projections—complicate state and local decisions to justify the current costs of adaptation efforts for potentially less certain future benefits. <sup>25</sup> We recommended that the appropriate entities within the Executive Office of the President develop a strategic plan for adaptation that, among other things, identifies mechanisms to increase the capacity of federal, state, and local agencies to incorporate information about current and potential climate change impacts into government decision making. USGCRP's April 2012 strategic plan for climate change science recognizes this need by identifying enhanced information management and sharing as a key objective.

Our April 2013 report on infrastructure adaptation concluded that the federal government could help state and local efforts to increase their resilience by (1) improving access to and use of available climate-related information, (2) providing officials with improved access to local assistance, and (3) helping officials consider climate change in their planning processes. <sup>28</sup> In April 2013 we recommended, among other things, that the Executive Director of USGCRP or other federal entity

<sup>&</sup>lt;sup>24</sup>To examine consideration of climate change in U.S. infrastructure planning, we visited a nonprobability sample of seven selected locations where decision makers had undertaken such planning—three locations focused on roads and bridges (Washington State Route 522; Interstate-10 Twin Span Bridge near New Orleans, Louisiana, and Louisiana State Highway 1), two locations focused on wastewater management systems (King County Wastewater Treatment Division in Washington and the Milwaukee Metropolltan Sewerage District in Wisconsin), and two National Aeronautics and Space Administration centers (Johnson Space Center in Houston, Texas, and Langley Research Center in Hampton, Virginia).

<sup>&</sup>lt;sup>25</sup>GAO, Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions, GAO-10-113 (Washington, D.C.: Oct. 7, 2009).

<sup>&</sup>lt;sup>26</sup>GAO-13-242.

designated by the Executive Office of the President work with relevant agencies to identify for decision makers the "best available" climate-related information for infrastructure planning and update this information over time, and to clarify sources of local assistance for incorporating climate-related information and analysis into infrastructure planning, and communicate how such assistance will be provided over time. They have not directly responded to these recommendations, but the President's June 2013 Climate Action Plan and November 2013 Executive Order 13653 on Preparing the United States for the Impacts of Climate Change drew attention to these issues.<sup>27</sup> For example, the Executive Order directs numerous federal agencies, supported by USGCRP, to work together to develop and provide authoritative, easily accessible, usable, and timely data, information, and decision-support tools on climate preparedness and resilience.

We also have work under way exploring, among other things, the risk extreme weather events and climate change pose to defense facilities, public health, agriculture, public transit systems, and federal insurance programs. This work—within the framework of the February 2013 high-risk designation—may identify other steps the federal government could take to limit its fiscal exposure and make our communities more resilient to extreme weather events.

Chairman Carper, Ranking Member Coburn, and Members of the Committee, this concludes my prepared statement. I would be pleased to answer any questions you have at this time.

## GAO Contact and Staff Acknowledgments

If you or your staff members have any questions about this testimony, please contact me at (202) 512-3841 or gaffiganm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement. Alfredo Gomez, Director; Michael Hix, Assistant Director; and Heather Chartier, Diantha Garms, Cindy Gilbert, Richard Johnson, Joseph Dean "Pep" Thompson, and Lisa Van Arsdale made key contributions to this testimony.

<sup>&</sup>lt;sup>27</sup>More information on the June 2013 Climate Action Plan and Executive Order 13653 can be found here.

# TESTIMONY OF COLLIN O'MARA SECRETARY OF THE DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL BEFORE

# THE U.S. SENATE COMMITTEE ON HOMELAND SECURITY AND GOVERNMENT AFFAIRS HEARING ON EXTREME WEATHER EVENTS: THE COSTS OF NOT BEING PREPARED

### **FEBRURARY 12, 2014**

Chairman Carper, Members of the Committee, thank you for inviting me to testify before you today. As the lowest-lying state and among the most vulnerable to extreme storms, sea level rise, and other climate impacts, Delaware strongly supports the efforts of Chairman Carper and focus of this Committee on the costs and consequences of not being prepared for extreme weather events.

The conversation that we are having today about improving resiliency is critical to states and communities across the country and could help save tens of billions of dollars annually. As we have seen from recent events across the nation, we are staggeringly unprepared for extreme weather events. In recent years, Delaware has been affected by extreme storms including Irene and Sandy, inland and coastal flooding, and droughts and heat waves—all of which have impacted our citizens, economy, and have disrupted critical infrastructure and services.

In Delaware, we know that protective measures work and prove the old adage that an ounce of prevention is worth a pound of cure. Nourished beaches help protect Delaware's multi-billion tourism economy at a cost of well less than 1% of the value of the assets that they are defending. Areas with healthy wetlands or other natural defenses suffer a fraction of the damage compared to communities without. Communities exceeding National Flood Insurance Program requirements are significantly better equipped to face storm events.

As we speak, Delaware is taking a wide range of proactive measures at the local level to increase resilience and preparedness to the impacts of extreme storms. These actions will reduce damage at a fraction of the cost compared to rebuilding after the fact. We have adopted a three-prong approach that we believe can serve as a model for any community looking to improve their resiliency:

- Start with Sound Science and Economics: Strategically improving resilience requires that
  any state, community, or tribe clearly assess vulnerabilities and stressors. To this end,
  Delaware has conducted some of the most comprehensive assessments of our
  vulnerabilities in the nation:
  - Extensive analysis of floodplain vulnerabilities: As a result of growing challenges
    from inland and coastal flooding, Governor Markell signed legislation establishing a
    Drainage and Floodplain Advisory Committee, which was charged with developing
    recommendations for common-sense standards to mitigate flood damage to public

infrastructure, natural resources, and private property. Specifically, the committee focused on minimizing the flooding of water supply and sanitary sewage disposal systems, maintaining natural drainage, reducing financial and emergency response burdens imposed on the state, local community, its governmental units and its residents, by discouraging unwise design and construction of buildings in areas subject to flooding, reducing prolonged business interruptions and damage to public facilities and other utilities, and ensuring greater accountability by those who build in and occupy special flood hazard areas should assume responsibility for their actions. As part of this effort, the committee identified the importance of updating floodplain maps in partnership with FEMA to ensure that current information drives decision-making.

- Sea Level Rise: A few years ago, we established an Advisory Committee to help plan for sea level rise. The committee was composed of members from a wide variety of interest groups including state agencies, local governments, citizen organization, business organization, and environmental organization. The goal of the committee was to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses and citizens to enable them to adapt programs, policies, business practices and make informed decisions. The final report analyzes more than 75 types of assets, including public safety, infrastructure, societal, economic and natural resource, to determine the level of vulnerability under three different inundation scenarios. Sixteen statewide resources ranked as being of high concern, including protective beaches/dunes and coastal impoundments, evacuation routes, heavy industrial areas including the Port of Wilmington, public drinking supply wells and other water infrastructure, and protected lands, all of which are atrisk for some level of increased permanent inundation.
- Climate Change Impact Assessment: In addition to the extensive analysis of Sea
  Level Rise, we gathered Delaware's leading scientists and practitioners to form a
  Climate Change Steering Committee, which has produced a report to localize the
  science and the anticipated impacts on five key sectors: public health, water
  resources, agriculture, ecosystems and wildlife, and infrastructure. The Assessment
  serves as a tool to guide our actions with the best available science and is helping
  state agencies and local governments understand the short-term effects of climate
  change such as extreme heat waves, intense rainfall events, and increased storm
  surge as well as long-term impacts from sea level rise, longer growing seasons, and
  milder winters.
- Bay Beaches Economic Analysis: The Delaware Bay Beach Working Group is
  evaluating a range of management options for the Bay Beaches, including engineered
  beach nourishment, strategic retreat, and no-action. The group completed a highly
  detailed cost-benefit analysis to understand where the benefits accrue (public versus
  private benefit) and help determine the appropriate level of public investment and
  local cost-share.

- Economic Analysis of the Contribution of the Coastal Economy: A 2012 economic report by the University of Delaware stated that the total economic contributions of coast-related activity to the State of Delaware include \$6.9 billion added to total industry production, 59,000 additional jobs, and \$711 million of additional local, state and federal taxes.
- 2. Invest Strategically with Preference for Natural Systems: With scientific and economic analyses in hand, it is critical to triage existing infrastructural deficiencies and invest in priority areas to improve the resiliency of defenses against flooding and storm surge. Delaware has placed particular focus on accelerating the use of natural infrastructure to improve our resiliency, particularly in coastal areas, low-income communities, for critical industries and areas with hazardous materials. Numerous projects are currently underway or recently completed across the state, ranging from large wetland restoration projects in South Wilmington and the Inland Bays; beach nourishment along the Delaware Bay and Ocean Coast in partnership with USACE, and Living Shoreline projects in the Inlands Bays and the tributaries of the Delaware Bayshore. To deliver these projects, we have worked closely with the Department of Interior, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, local governments, and conservation partners including The Nature Conservancy, Partnership for the Delaware Estuary and the Center for the Inland Bays, Delaware Nature Society and Delaware Wildlands.

In addition, we continue to strengthen existing or failing infrastructure including dams, dikes/levees, and coastal impoundments, as well as modernize stormwater infrastructure and drainage projects—nearly entirely at state expense.

- 3. Build in Resiliency Going Forward: In addition, we are updating fundamental policies to ensure that future development and redevelopment are much more resilient:
  - Modernized Stormwater Regulations: Our agency recently promulgated significant
    updates to the state's stormwater regulations. Unlike the previous rigidly prescriptive
    program, the updated regulations establish clear performance standards but allow
    developers and engineers to comply with the standards in the most cost-effective
    manner for a particular site. This provides much greater flexibility, while achieving
    better results.
  - Floodplain and drainage standards: Through the Drainage and Floodplain Advisory
    Committee, the State provided all local governments with actionable
    recommendations for improving drainage codes and floodplain standards, as well as
    model ordinances for adoption. We are currently working one-on-one with local
    governments to implement the updated standards.
  - Executive Order 41 "Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing Emissions": EO41 directs state agencies to improve resiliency by recognizing the risks of flooding and sea level rise, developing

implementable strategies for adaptation and preparedness to temperature and precipitation fluctuations, and setting goals for greenhouse gas reductions.

As a result of these proactive efforts, President Obama asked our Governor, my boss Jack Markell, to serve on his Task Force on Climate Preparedness and Resilience. The Task Force is comprised of Governors, Mayors, and Tribal leaders, who are charged with making recommendations about how federal agencies can help communities nationwide improve their resilience to the impacts of climate change. The Task Force recently convened for the first time and is setting up four subcommittees to develop specific recommendations about storm response and recovery, natural resources, built infrastructure, and public health. Based upon our experience in Delaware, we have been asked to lead the Natural Resources Subcommittee and Task Force Co-Chairs Nancy Sutley, Chair of the Council on Environmental Quality, and David Agnew, Director of Intergovernmental Affairs, have visited Delaware to see firsthand our natural infrastructure efforts to alleviate flooding in the Southbridge neighborhood in the City of Wilmington through a comprehensive wetland restoration project.

Through all of these experiences, including working closely with our strong federal partners, we offer a few recommendations for the Committee's consideration:

- Build resiliency standards into all federal investments and funding: Improving preparedness for extreme storms does not require a new bureaucracy, but rather should be incorporated into all relevant existing programs and funding mechanisms. Grant programs that support infrastructure, such as U.S. Department of Transportation's Federal Highways matching funds, the Clean Water and Drinking Water State Revolving Funds administered by the Environmental Protection Agency, and the Department of Housing and Urban Development's Community Development Block Grant, could all readily incorporate improved storm resiliency into project design and implementation as requirements for funding and project approval. Federal funds should no longer support projects that are insufficiently resilient to withstand predictable storm events—it's just throwing good money after bad. In addition, federal facilities should lead by example and model best practices resiliency, just as Delaware is working to do through the implementation of Governor Markell's EO 41.
- Invest in protection today to save money on response tomorrow: The U.S. Army Corps of Engineers will spend more money on storm response through the Hurricane Sandy Supplemental Appropriation than was spent in the previous fifty years combined on protection projects (\$5 billion versus an average \$100 million annual appropriation). Our experience in Delaware suggests that for every \$1 invested in shore protection we are getting at least \$10 in storm protection value not including the added value of the dunes to environmental, recreation and jobs sectors of the economy. The protection projects nationally cost a fraction of the value of the assets they protect and prevent billions of dollars in FEMA claims annually, yet these budget lines continue to be decreased, while payouts for storm response soar beyond FEMA budget allocations. Budgets are tight, but investments that could save billions of dollars in avoided costs must score better during the budget and appropriations processes.

Part of the disconnect stems from the way in which costs and benefits are calculated in the budgeting process. Investment in resiliency measures most often return value far beyond what is accounted for by the agencies in their budget requests. We have a perfect opportunity right now, as agencies are working with local governments to repair and rebuild the areas damaged by Hurricane Sandy there, to quantify the economic savings realized where well-built and maintained coastal defenses were in place and protected communities—and to compare that data to the impacts in communities, which suffered significant damages from storm surge and waves, because there were no defenses or dune systems did not hold. Quantifying this savings due to beaches, dunes, and other natural systems that held would greatly help inform future investment decisions.

- Break the Disaster-Rebuild-Disaster cycle: Severe storms create opportunities to rebuild using improved designs or by relocating to less vulnerable locations. Greater emphasis needs to be placed on rebuilding smarter, rather than just rebuilding quickly without any long-term reduction in vulnerability. We have worked with the Georgetown Climate Center on several common-sense recommendations to this effect and we are supportive of the thoughtful work of the Hurricane Sandy Rebuilding Task Force. While FEMA's public assistance programs have provisions in the Stafford Act to enable damaged facilities to be rebuilt to higher standards, these opportunities are often squandered in the rush to provide assistance as quickly as possible. Further, the National Flood Insurance Program (NFIP) claims adjustment process contributes to this problem as well by rushing to pay claims as quickly as possible, increasing the likelihood that property owners will repair in an unsafe manner, even in instances where buildings have been substantially damaged triggering mandatory elevation requirements.
- Prioritize comprehensive protection projects: Significant opportunities exist to deliver USACE-led protection projects more cost effectively and save taxpayers millions of dollars annually. We strongly believe in maximizing the beneficial reuse of material dredged from navigational channels to address beach, wetland, and island erosion/losses by employing the Regional Sediment Management (RSM) practices. Often these integrated projects do not meet the USACE "lowest-cost test" for evaluating projects because the project benefits cross business lines and avoided costs are often unaccounted. As a result, two projects, for example a navigation project and an adjacent coastal projection project, may cost significantly more when completed individually, compared to a combined comprehensive project which may have cost 10-20% more than either individual stand-alone project but could have saved significant tax dollars if integrated together. Delaware is executing two such comprehensive projects right now in Bowers Beach and in our Inland Bays (Pepper Creek) that are producing cost-savings of 40-60% compared to the normal stove-piped way that the USACE traditionally does business.
- Ensure sound science is the foundation of decision-making: NFIP flood studies and flood
  risk maps remain a key part of community resiliency programs, yet fall short of depicting
  true risk. These models and maps are used in land use planning, building design and flood
  mitigation projects yet they omit critical risk factors. Future flood levels in coastal areas with
  rising sea levels are not shown. Future flood levels in riverine floodplains in areas with

watershed changes which are causing increased runoff are not shown. Barrier Island impacts such as erosion, breaching or inlet formation during severe storms are not considered and lead to underestimates of flood levels in back bays. More robust modelling approaches are available, but are not being used in FEMA's mapping programs. Higher locally-mandated construction standards are a way to offset these mapping deficiencies, but as long as FEMA's flood mapping products are used to communicate risk, and do not reflect known increases in risk, they may actually contribute to increased vulnerability of future development.

- Continue modernizing key policies: NFIP Floodplain Management Regulations have been used nationwide by communities for local floodplain regulations. The NFIP Regulations are widely considered to be an insufficient standard for flood-prone communities to remain sustainable, and for the flood insurance program to remain financially stable (subsidized flood insurance premiums are also a contributing factor). NFIP floodplain Regulations have not been changed since 1989 and should be modernized, especially in light of my earlier point that floodplain maps often reflect a relatively low standard of flood risk. Updating these standards will require FEMA and the states to provide more technical assistance to local governments. In the absence of such an effort, some states such as Delaware, and many communities, will continue to develop and implement higher standards, but far too many will continue to regulate their floodplains only to the minimum national standards, leading to increasing expensive vulnerability which we cannot afford at any level of government.
- Prioritize natural infrastructure: Delaware's experiences show that natural infrastructure, especially nourished beaches, living shorelines, and healthy wetlands, can effectively mitigating a range of storm damage. They also have the added benefit of improving water quality, providing recreational amenities, and supporting wildlife and fishery habitat. Federal programs should prioritize natural infrastructure solutions wherever practicable and recognize the cost-effectiveness of utilizing natural infrastructure to provide co-benefits in other areas. We have been working closely with The Nature Conservancy and other conservation partners to implement several projects that we believe could serve as national models.
- Stop rewarding communities that fail to prepare: Some states and local governments have spent significant local resources to improve the resiliency of their communities, while others spend virtually nothing despite their ability to invest (low-income and environmental justice communities should be considered separately). When a disaster hits, the communities that have used their own resources (and as a result suffer less damage) are effectively penalized through the nearly full reimbursement of damages for the unprepared communities, which is effectively a large subsidy for less responsible communities. Delaware continues to be frustrated by the determination that states that received FEMA Public Assistance grants after Sandy (and not Individual Assistance grants) were ineligible for any Community Development Block Grant funding from the Sandy Supplemental, despite the state's prior strategic investments being the primary reason for submitting fewer claims compared to other jurisdictions. This policy disincentives states and localities to use local resources to improve resiliency proactively and encourages states to overestimate damages—both of which place more burden on the federal government in an area where there should be greater local accountability.

- Ensure that public expenditures produce a public benefit: Investment of limited resources for resiliency should be focused upon infrastructure that has the largest public benefit, rather than subsidizing private property or activities. Those who benefit the most from public investment in resiliency efforts should contribute proportionally to the project costs, taking into account the ability of a community to pay. For example, Delaware is using economic analyses to determine the appropriate cost-share ratio for local protection projects that do not qualify for federal assistance.
- Focus early on hazardous sites: Much attention on storm resilience focuses on coastal communities and residential impacts, but some of the most potentially destructive impacts will likely result from the inundation or washout of legacy-contaminated sites. Delaware has begun giving greater prioritization to the remediation of these sites, but we have run into problems when trying to access FEMA funds to acquire and demolish unsafe, flood-prone properties when the sites have underlying contamination. These sites are deemed ineligible for demolition grants for federal liability reasons, yet they pose a much greater health risk than other sites that are just bricks and mortar. For another example, the US military has had a long-standing presence along our coastlines to protect the homeland. Some past practices have resulted in the creation of contaminated sites in areas particularly vulnerable to coastal storms and sea level rise, yet these sites are often treated no differently in calculating risk and thus priority for remediation whether they are located along a major water-body or completely landlocked.
- Ensure local involvement in projects: Given the site-specific nature of resiliency work, it is
  critical that broad public participation informs local decisions. Avoid unnecessarily
  prescriptive adaptation actions and empower decisions to be made at the local level.

We thank the Committee for holding today's hearing on reducing costs by improving preparedness for extreme storms. Nearly sixteen months after Sandy and with the recovery well underway, now is the time to update the underlying policies and funding mechanisms that will significantly mitigate damage from future storms.

I look forward to your questions.

# Testimony for the US Senate Committee on Homeland Security and Governmental Affairs "Extreme Weather Events: The Costs of Not Being Prepared"

Wednesday, February 12, 2014

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I appreciate this opportunity to come before this Committee in regard to the benefits of cities being prepared to manage present extreme climate impacts and the increasing threats in the future due to climate change. I have been conducting research and consulting on how to manage the impacts of the changing climate on New England infrastructure for 15 years. Over that time, I have conducted several studies on the long-term economic consequences of cities being impacted by 1) extreme amounts of precipitation occurring during storms and 2) coastal flooding from coastal storm surges during hurricanes (tropical storms) and winter storms (extra-tropical storms, known locally as nor'easters). Here I compare the long-term costs of not being prepared for these present and future threatening events to the benefits of being prepared. Because of the changing climate, climate change impacts on extreme events are part of the analyses. The costs I present may actually underestimate the actual damage costs because these types of costs are not included in the analyses; human deaths and injury; damages to ecosystems and the services they provide (and upon which infrastructure depends such as the flood and water quality mitigation values of coastal wetlands); and indirect costs such as lost employment and business activities, and community displacement and disruption.

Metropolitan Boston and Coastal Flooding: With funding from the US EPA over the period from 1999 to 2004, my colleagues and I investigated integrated adaptation strategies for metro Boston (Kirshen et al, 2008a). The study area shown in Figure 1 was divided into 7 subareas or zones, of which Zones 1 through 4 are directly coastal. When this research was done in the late 1990s, less data were available for these types of studies than exist now (eg, very accurate elevation data was not available), but the results are still representative of the costs. While in reality in every zone there would be a mix of adaptations actions taken in different locations and time periods (Kirshen et al, 2014), we assumed that in each zone only one adaptation action could be taken. Details of the methodology and results are in Kirshen et al (2008b). For each zone we determined a reasonable adaptation action from the choices of:

- · No Action: taking no actions and rebuilding after each damaging event.
- Protection: construction of a barrier to lessen the impacts of the climate changes, such as a seawall to protect against more coastal flooding.
- Accommodation: allowing the impacts to occur but attempting to lessen them by taking specific actions. Examples of accommodation actions are flood proofing, flood evacuation, elevating buildings, and purchasing insurance.

 Retreat: moving away from the impact. An example of retreat is leaving a floodplain.

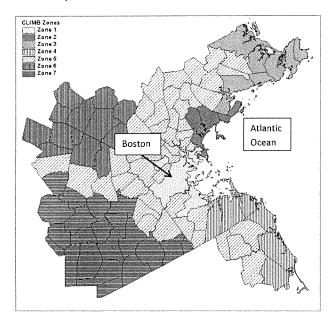


Figure 1. Planning Zones for Metro Boston used in Kirshen et al (2008a)

Using Monte Carlo simulation, we then determined total damages from surge flooding to residential, commercial and industrial buildings over the next 100 years assuming sea level rises (SLR) of both 0.6 m (approximately 2 feet) and 1.0 m (just over 3 feet) with and without adaptation being taken. In the late 1990s, these SLR projections were considered plausible ranges. The US National Climate Assessment now considers both to be at the low end of the plausible range in 2100 (Parrish et al, 2012). Thus these results underestimate the costs of damage due to SLR.

The results are in Table 1 for both SLR scenarios. Column 3 is the total damage and emergency costs over this time period assuming no actions are taken. Column 4 is total adaptation costs when adaptation is undertaken. Column 5 is the cost of the damages that occur even though adaptation has been undertaken, so-called residual damages. Column 6 is the benefit of taking adaptation measured by the costs avoided by undertaking adaptation, which is calculated as the difference of Column 3 and 5. Column 7 is the ratio of Column 6 to Column 4.

(1) Location	(2) Reasonable Adaptation Action	(3) Expected Value Total Damages from 2000 to 2100 taking No Action (5 billion) 1.0 M SLR	(4) Expected Value Total Costs of Adaptation (\$ billion)	(5) Residual Damages (\$ Billion)	(6) Expected Value Total Costs Avoided (benefit) (\$ billion	(7) Benefit: Cost Ratio
Zone 1, South Urban (essentially Boston and Quincy)	Protection	14.9	0.4	2.0	12.9	32.9
Zone 2, North Urban	Protection	7.8	0.5	1.2	6.6	13.1
Zone 3, North Suburban	Accommodation	6.2	0.5	1.2	5.0	10.0
Zone 4, South Suburban	Accommodation	5.7	0.4	1.2	4.5	12.7
		0.6 M SLR	By 2100			
Zone 1, South Urban (essentially Boston and Quincy)	Protection	7.8	0.4	2.2	5.6	14.3
Zone 2, North Urban	Protection	4.5	0.5	1.3	3.2	6.4
Zone 3, North Suburban	Accommodation	3.4	0.3	0.7	2.7	9.6
Zone 4, South Suburban	Accommodation	3.4	0.3	0.7	2.7	10.4

#### Table1. Benefits and Costs of Adaptation in Metro Boston

As expected, a protection approach is favored in heavily urbanized Zones 1 and 2 to protect valuable, densely built-up areas. Flood proofing, elevating buildings, and other accommodation actions are reasonable for less developed areas. In all cases, the benefit-cost ratios are greater than 1.0. In fact, the benefits of adaptation are particularly positive for very developed areas. The benefit: cost ratios are less under the 0.6 m SLR because the damages are less while adaptation costs do not change as much. The residual damages to Zones 1 and 2 are slightly greater under the 0.6 m SLR scenario than the 1.0 m scenario because the algorithm requires adaptation to take place after the first storm that is greater than the present 100 Year storm occurs. The first 100 Year storm in the 0.6 m SLR scenario occurs later than in the 1.0 m SLR scenario; thus more residual damage can occur in the 0.6 m scenario before adaptation occurs.

In none of the scenarios is taking No Action the more reasonable action in terms of costs.

**Hampton-Seabrook-Hampton Fall NH and Coastal Flooding.** These three towns are located on the NH coast as in Figure 2. All the towns have many second homes, but particularly

Hampton and Seabrook on the barrier beach. Under a grant from the US EPA, we examined the benefits and costs of protecting privately owned buildings (i.e., homes and commercial facilities) and key public assets (e.g., sewage treatment plants, schools, fire and police stations) from present and future coastal storms (Merrill et al, 2012). We developed adaptation plans to protect to 2050 under low and high SLR scenarios of approximately one feet to two feet. To protect public assets, we estimated threshold elevations at which they will be impacted by flooding. Adaptation using flood walls is undertaken when the 100 year flood equals or exceeds the threshold elevation. We determined the possible time of this occurring under both high and low SLR scenarios. We assume the current trajectory of SLR is known and that the adaptation action will be taken just before the threshold is exceeded. Moreover, we also assume the assets will be protected from larger, very low frequency events (e.g., the 500 year flood) by temporary actions such as sandbagging.

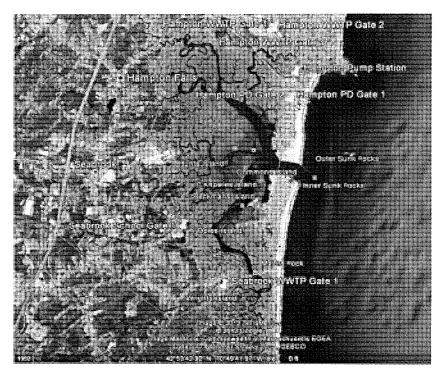


Figure 2. Hampton-Seabrook-Hampton Fall NH

For modeling adaptation actions for private assets, it was assumed these properties will be proactively protected by flood proofing to the 2100 100 Year flood level according to a

regulation that states if a building is damaged by a flood, it must protect to the 2100 100 Year flood level when rebuilt. We assumed two possible adaptation actions here. The first is that they are required to adapt to the 2100 flood level assuming high SLR. The second is that they are required to adapt to the 2100 flood level assuming low SLR. In either case, since this regulation is being implemented as floods occur, regulators do not know what the future may be. Therefore, we modeled all the possible outcomes. Under the high and low SLR scenarios, we determined the costs of adaptation and compared them to the discounted expected value of the damages avoided by adaptation. With the high SLR regulation, the region would also be protected against the low SLR scenario occurring, but extra adaptation costs would have been incurred. With the low SLR regulation, if high SLR actually occurs, then residual damages will result. The results for Hampton are in Table 2.

Scenario	Adaptation Option	Expected Value Total Discounted Damages from 2010 to 2050 taking No Action (\$ million)	Expected Value Total Discounted Costs of Adaptation (S million)	Residual Discounted Damages (\$ million)	Expected Value Total Discounted Costs Avoided (benefit) (\$ million)	Benefit: Cost Ratio
		Critical Public Assets				
High SLR	Protect to 2100	82.7	7.1	0	82.7	11.6
Low SLR	Protect to 2100	78.8	4.9	0	78.8	16.1
		Private Assets				
High SLR	Protect to High SLR 2100 Flood by Regulation	318.8	40.5	0	318.8	7.9
Low SLR	Protect to High SLR 2100 Flood by Regulation	287.7	40.5	0	287.8	7.1
High SLR	Protect to Low SLR 2100 Flood by Regulation	318.8	36.0	31.1	287.7	8.0
Low SLR	Protect to Low SLR 2100 Flood by Regulation	287.7	36.0	0	287.8	8.0

Table 2. Critical Public Assets, Hampton NH.

As can be seen, no matter what combination of SLR scenarios and adaptation actions, the benefit-cost ratios are greater than one. They are particularly large for protecting the expensive public assets from extreme events. Similar results were found for Hampton Falls and Seabrook.

Somerville MA and Stormwater. With a 2010 population of 75,754 over an area of approximately 11 square kilometers, Somerville MA is the most densely populated municipality in New England (see Figure 3). The city is highly urbanized, almost completely built-out, and

has limited open space. Our case study site was the Winter Hill neighborhood and the commercial Assembly Square area, which are serviced by a combined sewer system that carries both stormwater and sanitary waste. Presently, the system has the capacity to handle all the wastewater flow but can only handle additional storm flows resulting from small storms. When larger storms occur, some of the extra combined sewage is treated at the regional Deer Island Wastewater Treatment Plant, some of the combined waste is discharged partially-treated into the nearby tidal Mystic River, and there is flooding in streets with untreated sewage. In this project funded by US NOAA, we investigated the performance of several alternative strategies to manage the stormwater under present and future climates (Kirshen, et al, 2014). We developed plausible scenarios of increases in extreme precipitation by storm frequencies between the 2010 and 2070 and also for sea level rise in the Mystic River, which impacts the drainage capacity of the drainage network. We determined the expected present value discounted costs to the community of extra treatment costs at Deer Island, treating and discharging sewage into the Mystic River, and street flooding if no actions were taken now or in the future to respond to the impacts of increased storm precipitation and less drainage capacity due to higher sea levels. We found that separation of the presently combined system into separate storm and sanitary sewers was the most reasonable approach among the alternatives. The costs and benefits of this approach are in Table 3.

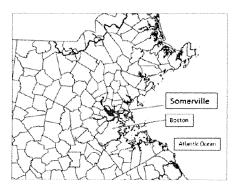


Figure 3: Location of Somerville MA

Climate	Total	Total	Total	Total	6) Benefit:
Change and SLR Scenario	Expected Present Value Total Discounted Costs from	Expected Present Value Discounted Cost of Sewer Separation	Expected Present Value Discounted Residual	Expected Present Value Total Discounted	Cost Ratio
	2010 to 2070 taking No Action (\$million)	(\$ million)	Damages (\$ million)	Costs Avoided (Benefit) (\$ million)	
Low	746.2	191.2	-6.0	752.2	3.9
Moderate	756.2	191.2	-5.8	762.0	4.0
High	769.1	191.2	-5.6	774.7	4.1

Table 3. Benefits and Costs of Sewer Separation in Winter Hill, Somerville MA, 2010-2070

The benefit-cost ratio is positive here over a plausible range of climate change scenarios; again indicating the value of undertaking adaptation to extreme events rather than just bearing the consequences.

Reaping the Benefits of Adaptation to Extreme Events and Climate Change. I have summarized some of my recent research on the benefits of adaptation to climate change compared to the costs of damages. Even with not all the damage costs included, in all the examples under a range of climate change and SLR scenarios investing in adaptation paid off in terms of damages avoided. Undertaking no adaptation was never the most reasonable action in terms of costs. With the benefit-cost ratios so high, these adaptation actions are probably beneficial even without climate change (i.e., no regrets actions). In order for a community, an industrial facility, or a military base to avoid the serious consequences of climate change and obtain these benefits, an adaptation planning process must be carried out now. This does not mean that the construction of all adaptation actions must be done now. Rather, as has been modeled in these examples, if an asset is not presently threatened by extreme events, the adaptation action can be under taken in the future when the threat is more evident. The key is to plan for the future now so adaptation actions can be reserved for the future, implemented when needed, and decisions are not taken now that make hinder the implementation of an action in the future. It may also be possible to implement infrastructure adaptation actions when the infrastructure is scheduled for regular rebuilding. Adaptation plans can also be implemented as zoning and master plans are updated. Such actions can help lower the costs of adaptation. A good summary of adaptation planning is in Kirshen et al (2014) and in Rosner et al (2014).

Thank you for this opportunity and I am glad to take any questions or comments.

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# **Testimony of Lindene Patton** Zurich Insurance Group, Ltd. February 12, 2014

## Closing the Extreme Weather Resilience Gap

Chairman Carper, Ranking Member Coburn, distinguished Members of the Homeland Security and Government Affairs Committee, my name is Lindene Patton. I am employed by a U.S. subsidiary of the Zurich Insurance Group (the Group) and serve as the Chief Climate Product Officer for the Group.

Zurich is a global insurance company providing insurance and risk management solutions to customers in 170 countries. It has been serving customers in the United States since 1912, and today stands as the third largest commercial property-casualty insurer in the country, with over 8,000 employees nationwide.

I would like to begin my testimony by thanking you for holding this timely hearing. I look forward to sharing with the Committee an insurance industry perspective on the current state of our nation's resilience to extreme weather events and the economic importance of investing today in improving resilience.

Zurich observes that the US is increasingly reliant on disaster recovery funding to respond to extreme weather events<sup>1</sup> and underinvested in resilience – physically<sup>2</sup> and economically<sup>3</sup>.

Zurich maintains that insurance has a unique capacity to facilitate resilience like no other financial instrument. Insurance provides risk assessment, risk management and risk-based price signals – all of which help signal risk magnitude and risk reduction priorities to stakeholders. To reduce reliance on disaster recovery funding, increased collaboration with insurers and reliance on risk based price signals will be required because the insurance mechanism is the best indicator of risk that the market economy can provide.

Future improvements to our nation's resiliency require coordinated risk management involving the best tools government and insurers have available.

<sup>&</sup>lt;sup>1</sup> "Federal Financial Exposure to Natural Catastrophe Risk" J.David Cummins, Michael Suher, and George Zanjani (2010),

http://www.infrastructurereportcard.org/a/browser-options/downloads/2013-Report-Card.pdf

American Society for Civil Engineers (ASCE) March 2013, Report Card for America's Infrastructure.

<sup>&</sup>lt;sup>3</sup> Id Cummins and BIS Working PapersNo 394, Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes by Goetz von Peter, Sebastian von Dahlen, Sweta Saxena , Monetary and Economic Department December 2012

Assuring resilience to extreme weather events requires risk management before, during and after a loss event. If our response to extreme weather events is only after they occur, society has squandered its best opportunity to control risks and costs related to these events, creating an unmanaged, unbudgeted exposure.

Zurich's mission is to help our customers understand and protect themselves from risk. Our business philosophy is centered on planning for risks, and assuring the capacity and capability to respond to both the expected and unexpected extreme event. Zurich understands the importance of pre-event investments in resilience, and therefore, acts accordingly by committing time and money to support resilience initiatives for our company, our customers and the communities where we work and serve. We are very proud of our efforts and to give context, some examples of actions taken by Zurich to share knowledge with stakeholders on improving resilience of assets and of direct Zurich investments in improved resilience include:

- Since 2007, Zurich has through a formal initiative explored risk management issues relating to the role of insurance in society in providing economic resiliency, education, pre-event risk reduction and disaster management training, and post-event loss mitigation.
- In 2008, Zurich announced, as part of its global climate initiative, that it would
  dedicate significant resources and apply its skills in the area of risk management
  to assist stakeholders in adapting to and mitigating the risks of climate change.
  As one example of related activities, since 2011 Zurich has allowed me to accept
  a personal appointment to the US National Climate Assessment to share
  expertise and knowledge to further the understanding of the state of the science
  related to severe weather events and needed resilience. Many other examples
  exist.
- Since 2009, Zurich has been instrumental in the work of the World Economic
  Forum assessing and evaluating the inter-connectedness of risk through
  development and issuance of the Global Risk Report
  provides insights into the importance of extreme weather interconnectedness to
  key economic functionalities in global society, affirming the importance of risk
  mitigation to minimize negative economic disruption and other consequences.
  This work highlights that physical resilience to extreme weather events is

<sup>&</sup>lt;sup>4</sup> The latest Global Risk Report can be found at <a href="http://www.weforum.org/reports/global-risks-2014-report">http://www.weforum.org/reports/global-risks-2014-report</a>, "the Global Risks 2014 report highlights how global risks are not only interconnected, but also have systemic impacts. To manage global risks effectively and build resilience to their impacts, better efforts are needed to understand, measure and foresee the evolution of interdependencies between risks, supplementing traditional risk-management tools with new concepts designed for uncertain environments"

inextricably interconnected to economic stability (or instability where resilience is insufficient or deteriorates).

- In 2010, Zurich developed its Supply Chain Insurance and Risk Management Services program for insureds. This program was specifically designed to assist customers to evaluate risks to their supply chain, identify vulnerabilities, prioritize responses and set up physical, operational and financial risk management systems to address those risks so that when disaster strikes, including extreme weather events, global and local risks are managed so that business continuity is achieved and business proceeds with minimal disruption. Today only 8% of businesses have business continuity programs with their suppliers according to the Business Continuity Institute (BCI); BCI further notes that approximately 40% of disruptions are caused by severe weather events.<sup>5</sup>
- In 2011 Zurich worked with the World Economic Forum to research, write and
  publish "A Vision for Managing Natural Disaster Risk", which focused on the
  importance of public private partnerships to achieving resilience for
  communities, rather than just individual assets.
- In 2012 Zurich launched its flood resilience initiative in conjunction with the
  International Federation of Red Crescent (the Red Cross). Through this program,
  we seek to demonstrate the benefits of pre-event risk reduction over post-event
  disaster relief, and improve public dialogue around flood resilience on the
  ground.
- In March 2013, we announced that we will enhance our existing cooperation with the International Federation of Red Cross and Red Crescent Societies (IFRC) with a commitment of up to CHF 21 million over five years. Together with the IFRC and Red Cross national societies, Zurich is putting in place community flood resilience programs in both urban and rural settings, starting in Mexico and Indonesia. These two programs will serve as models for future efforts that build on our risk engineering and analytical skills, and complement the on-the-ground knowledge and experience of the IFRC. In these countries we are also testing ways to measure community flood resilience against key indicators.
- In the Gulf Region, Zurich has worked closely with public officials and the private sector to improve resilience and economic sustainability in New Orleans.
   Activities from this resilience initiative have been consistent, numerous and varied, ranging from working with Habitat for Humanity to building storm resistant homes to improved disaster response to ongoing economic investment. As an example, in response to Katrina, our longstanding partnership

<sup>&</sup>lt;sup>5</sup> Business Continuity Institute Survey, November 2013

- in the St. Bernard Project $^6$  a non-profit organization established in March 2006 to rebuild homes destroyed by Hurricane Katrina.
- In 2013, the St Bernard Project was expanded to support activities for post-Sandy rebuilding. As part of Zurich's and its employees' commitment to rebuilding communities and helping to restore local economies following natural disasters, Zurich formed an alliance with St. Bernard Project and Tunnel to Towers. To date, Zurich employees have donated more than 2,000 volunteer hours to rebuild homes on Staten Island, helping rebuild 14 homes impacted by Sandy. In late July, the company announced a \$165,000 grant to St. Bernard Project to hire client services manager, a volunteer program manager and a construction site supervisor to support the rebuilding of an additional 60 Staten Island homes over the next year
- Over the years we have worked with progressive customers like Marriott to both demonstrate by design and implement cost beneficial extreme weather event risk mitigation solutions. For example, Marriott had one hotel that was damaged by hurricanes three times Hurricanes Frances, Jean and Wilma over a 12 month period in 2004 and 2005. We worked with Marriott to evaluate capital investment options for rebuilding with improved resilience; culminating in Marriott's upgrading of the facility to a Zurich Highly Protected risk (HPR) wind standard that reduced the predicted maximum probable loss (PML) exposure by \$135 million USD for a modest increase of capital investment of orders of magnitude less than the projected PML reduction.
- In 2013, Zurich worked with Verizon to address post-Sandy repairs and future facility extreme weather risk mitigation in Lower Manhattan; Zurich Risk Engineers and Underwriters collaborated with Verizon to design flood barrier walls, water intrusion barriers, and other facility retrofits to assure that when extreme weather occurs, risks of damage and service interruption from flood waters is eliminated or reduced to the levels of maximum expected probable
- Zurichhas supported the Institute for Building and Home Safety (IBHS) for years.
   Our support is focused on the study of commercial building resilience to wind, water, fire, and hail, committing hundreds of thousands per annum to research.
   In 2013 Zurich committed an additional \$1 million USD to research and sits on the Research Advisory Board for IBHS supporting its one of a kind testing facility in South Carolina.

<sup>6</sup> www.stbernardproject.org

- Zurich, through IBHS and directly in kind, has been active supporters of the Department of Homeland Security (DHS) 'Resilience Star' pilot<sup>7</sup> - a pilot which Zurich believes should be extended from its current residential scope to include both commercial and community applications.
- In 2013, Zurich announced a commitment to purchase \$1 Billion USD of green bonds focused on resilience from a program managed by the World Bank<sup>8</sup>, making Zurich a global leader in the purchase of such resilience supporting instruments. This innovative capital investment is focused on pro-active risk mitigation and adaptation to extreme weather events and is precisely the type of focused, directed, and purpose qualified capital investment, backed by the full faith and credit of a AAA rated institution that is required institutional capital at scale in sufficient amounts to close the resilience gap (e.g. improve community and asset resilience to extreme weather events to improve economic and social resiliency of communities.)

This work and the work of the larger insurance industry on risk management techniques may provide models for closing the current resilience gap.

### Roadmap to Resilience

My testimony will cover five aspects of understanding and improving our nation's resilience to extreme weather:

First, defining the extreme weather resilience gap;

Second, assessing the magnitude of the extreme weather resilience gap. Extreme Weather will cause economic disruption today and exponentially more economic disruption and other consequences in the future unless affirmative steps are taken to change this risk-accretive trajectory;

Third, the potential for the Insurance sector to provide valuable tools, skills, expertise and information, that are neither currently being effectively deployed nor leveraged to help society manage extreme weather risks and losses;

Fourth, the Federal Government has a significant ongoing role in disaster preparedness and recovery, that could be optimized through better coordination and collaboration with the insurance industry; and, finally,

<sup>&</sup>lt;sup>7</sup> https://www.disastersafety.org/resiliencestar <sup>8</sup> http://www.zurich.com/media/newsreleases/2013/2013-1118-01.htm

Finally, the concrete steps in the short term, medium term and long term that, if taken, would begin to close the resiliency gap, including but not limited to:

- the promotion of government and private investment in infrastructure resilience:
- the development of government policies and programs that send risk-based price signals;
- the elimination of government policies and programs that distort insurance
- the education of society on the true costs of extreme weather events and the personal and community economic benefits of improved resilience; and
- the promotion and enforcement of stronger building codes.

### Point 1: There is an extreme weather resilience gap

Currently in the United States, many privately and publicly held assets, from homes to critical infrastructure, are not sufficiently "resilient" to withstand extreme weather events.

The Department of Homeland Security defines resilience as '...the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.' The Department notes that a 'major component of resilience is the capacity of society's assets or its built environment to withstand or quickly recover from weather-related catastrophes...'

The World Bank defines resilience as '...the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to, and recover from the effects of hazard in a timely manner, including through the preservation and restoration of its essential basic structures and functions'. (Dickson, et. al, 2012).

Irrespective of which definition is applied, in the case of extreme weather events, significant assets and communities in the United States are not sufficiently resilient.

<sup>&</sup>lt;sup>9</sup> Appropriations request post Katrina Emergency Supplemental Appropriations for Hurricane Katrina Relief August 22, 2006 - RS22239; PL 109-62; 109-148; 109-174; 109-234; Sandy Relief PL 113-2 and others. The WEF Global Risk Report (ld.) cites extreme weather as one of the top ten global risks of concern.

One only need read the newspapers to affirm that in the face of named storms and other extreme events, large numbers of assets, and the communities that are defined by these assets and which support them, are not sufficiently resilient. Current risk management systems, engineering tools, land use policies, public and private insurance uptake and or disaster aid are not sufficient to incentivize or create asset resilience nor to facilitate rapid restoration of the asset and resiliency after an extreme weather event. Impacts of catastrophes, especially economic impacts, are not limited to single structures, dwellings or families, but are rather impacting entire communities and regions.

Look to the Gulf Coast, the coastal regions of New York and New Jersey – or to the Central Plains – and you will find individuals and communities that have not recovered months and in many cases years after an extreme weather event. In fact, in the US, the Business Continuity Institute (BCI) found that 45% of supply chain disruptions were caused by extreme weather events. BCI found that approximately 40% of businesses that were impacted by extreme events such as hurricanes for extended periods of time never recovered and never reopened. Thus, existing risk management systems and *ex post* disaster recovery efforts were not sufficient to restore all assets and communities or to restore them to a position where they would be more resilient in the face of future extreme weather events, which will be exacerbated by climate change. This and similar experiences illustrate the findings of the Bank of International Settlements Study<sup>10</sup> which states:

"...Our main results are that major natural catastrophes have large and significant negative effects on economic activity, both on impact and over the longer run.

However, it is mainly the uninsured losses that drive the subsequent macroeconomic cost, whereas sufficiently insured events are inconsequential in terms of foregone output. This result helps to disentangle conflicting findings in the literature, and puts the focus on risk transfer mechanisms to help mitigate the macroeconomic costs of natural catastrophes." (emphasis added)

A recent economics research paper confirmed through analysis that droughts and floods slow economic growth, thus affirming the importance of investment in resilience to extreme weather events. The European Commission Environment for Science newsletter summarized the report findings as follows:

"Droughts and floods can significantly damage economic growth, recent research has found. A 1% increase in the area affected by drought can slow a country's gross domestic product (GDP) growth by 2.7% per year and a 1% increase in the area experiencing extreme rainfall can reduce GDP growth by 1.8%, according to the study.

<sup>&</sup>lt;sup>10</sup> BIS Working Papers No 394, Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes by Goetz von Peter, Sebastian von Dahlen, Sweta Saxena, Monetary and Economic Department December 2012

Investments in water security could help reduce this negative economic impact, say the researchers."11

# Point 2: The magnitude of the resilience gap is sufficient to cause short, medium and long term economic disruption today and more so in the future unless affirmative steps are taken to change this risk-accretive trajectory

The resilience gap is large. How large? In 2010, Professor Cummins and co-authors projected that costs for the federal government share of unfunded disaster response costs for weather related disasters would grow to amounts within the range of the unfunded social security benefits over the same time horizon of 75 years: unfunded social security benefits are estimated to be approximately \$4.7 Trillion USD; and unfunded federal disaster assistance costs are estimated to range between \$1T USD and \$5.7T USD (all figures adjusted to 2008 dollars). 12 Cummins, et al. estimate that the special appropriations required to address federal disaster response costs to extreme weather events will range from \$1B USD for low loss years to \$100B per annum in 2008 dollars for high loss years 13.

Unfunded exposures of the state catastrophe funds are in addition to this number 14. The magnitude of state exposure from state natural catastrophe funds was estimated by the Government Accounting Office in a 20120 report at about \$3T USD15.

Another recent report found that both the frequency and magnitude of federal disaster relief for events causing loss in excess of \$1B USD is increasing at a significant rate and that federal disaster relief expenditures alone (which excludes supplementary charitable, state and local costs) over the last 3 years have risen to \$400 per household – more than a four-fold increase over the past 30 years<sup>16</sup>.

 $<sup>^{11}\,\</sup>underline{\text{http://ec.europa.eu/environment/integration/research/newsalert/pdf/359na1.pdf}}\,\text{citing Casey Brown, Robyn Meeks, Yonas}$ Ghile and Kenneth Hnu, "Is water security necessary? An empirical analysis of the effects of climate hazards on national-level economic growth", Phil. Trans. R. Soc. A2013 317, 20120416, published September 2013.

12. "Federal Financial Exposure to Natural Catastrophe Risk" J.David Cummins, Michael Suher, and George Zanjani (2010),

Corrected page 62 para 3 <sup>13</sup> ld. Cummins page 62 at para 3

<sup>&</sup>lt;sup>14</sup> Id. Cummins (2010) page 62 para. 3.

<sup>15</sup> Reports citing Citing GAO-10-568R Natural Catastrophe Insurance Coverage GAO 2010 at http://www.hawaiireporter.com/hurricane-sandy-pacific-tsunami-scare-expose-state-catastrophe-debts/123;

http://www.statebudgetsolutions.org/blog/detail/hurricane-sandy-tsunami-scare-expose-state-catastrophe-debts

16 "Disastrous Spending: Federal Disaster-Relief Expenditures Rise Amid More Extreme Weather", Daniel J. Weiss and Jackie Weidman, 29 April 2013 at http://www.americanprogress.org/wp-content/uploads/2013/04/WeissDisasterSpending-1.pdf

The US Government Accountability Office has also found these exposures to be of sufficient magnitude to warrant inclusion in the High Risk Series<sup>17</sup>.

Munich Re NatCatSERVICE data show that the number of loss-relevant weather catastrophes has increased significantly since 1980, globally and in North America<sup>18</sup>. In North America, the annual average number of natural catastrophe events (primarily, weather-related) has risen by four fold, from 50 to 200 in the last 30 years. <sup>19</sup> Even disregarding 2005 (a record year with Hurricanes Katrina, Rita and Wilma), overall and insured losses (adjusted for inflation) reveal an upward trend in the past three decades <sup>20</sup> – calculated before the Superstorm Sandy event. The rate of increase of the average number of annual natural catastrophe events (primarily, weather-related) in the United States is faster than the global rate of increase of 2.5 – based on an increase from 400 events in the 1980s to 1000 events in recent years. <sup>21</sup>

While taxpayers are bearing the burden of this increasingly unbudgeted risk and associated loss costs, some experts have suggested that the current approach to disaster funding may be unintentionally creating a 'stealth entitlement'<sup>22</sup>. From an insurers' perspective, this would manifest as an inhibitor for demand for our risk management products and services – a market distortion.

Without decisive risk reduction and management action by those tasked with managing risk – local, state and federal governments, as well as insurers, economically unsustainable accretive unbudgeted disaster management costs are projected to <sup>23</sup> continue on an upward trajectory.

This is not a concern unique to the United States. The European Union is currently struggling with these very issues and has recently issued a study on point called the EU Green Paper<sup>24</sup>. The EU Greenpaper notes:

"... Even where costs of major disasters are locally concentrated, if costs are inadequately covered by insurance then individual Member States may carry large fiscal burdens, which could cause internal and external imbalances." Noting further at page 12, section 3.0 "...Building resilience is a long-term effort that needs to be integrated in national policies and planning: resilience strategies are also part of the development

<sup>17</sup> See GAO-13-283 High-Risk Series

Munich Re, "Severe Weather In North America", Knowledge Series, 2012, page 22.

<sup>&</sup>lt;sup>19</sup> Id. at 19, Figure 3. <sup>20</sup> Id. at 22.

<sup>&</sup>lt;sup>21</sup> ld. at 19.

<sup>&</sup>lt;sup>22</sup> For a longer discussion on the concept of 'stealth entitlement' and natural catastrophe response costs, see "Federal Financial Exposure to Natural Catastrophe Risk," J. David Cummins, Michael Suher, and George Zanjani (2010).

<sup>&</sup>quot;Federal Financial Exposure to Natural Catastrophe Risk" J.David Cummins, Michael Suher, and George Zanjani (2010), Corrected page 62 para 3

<sup>&</sup>lt;sup>24</sup> EUROPEAN COMMISSION Strasbourg, 16.4.2013 COM(2013) 213 final GREEN PAPER on the insurance of natural and manmade disasters

process and contribute to different long-term policies, in particular climate change adaptation and food security."

The pattern of extreme weather event frequency and severity is predictable according to academics and other experts; and this science forms the basis for our industry's natural catastrophe modeling and underwriting processes. These predictive modeling processes are today the backbone of the underwriting standards for natural catastrophe and allow insurers to properly price risk. In addition to forming the foundation for pricing insured risk, the science related to extreme weather events suggests that a foundation for budgeting for resilience investments with a better return on investment might be defined from this predictable cash flow demand, as I discuss further in Point 5 of my testimony. In addition to industry proprietary models, open source platforms may be available to assist communities in such predictions in the not so distant future.25

# Point 3: Insurance has valuable data and analysis, tools and expertise that when leveraged to their greatest efficient capacity can help society manage these extreme weather risks and losses; disaster recovery funding is not a functional equivalent to insurance for these characteristics

The fundamental function of insurance is risk pooling. Insurance also provides a number of other critical functions that benefit individuals and society: risk assessment, risk management and risk pricing; and general social welfare value through security 26. Today, insurance is not being fully leveraged to solve the unfunded severe weather resilience gap.

For example, insurers use risk assessment, risk management and risk pricing data to inform customers about risks, consequences and options for resilience investments so they can take action to protect their assets. One of many examples of this service is the offering of Strategic Risk Management Solutions (SRM) by Zurich for its customers in 2008<sup>27</sup>. Part of SRM services includes the Total Risk Profile (TRP) tool which applies a risk identification methodology - in advance of loss to predict potential exposures and identify mitigation options . SRM even quantifies the risk so you can prioritize budget spending to fix the most impactful issues. Zurich

 $<sup>^{25}\</sup> https://connect.innovateuk.org/web/oasis-open-access-catastrophe-model.$ 

<sup>&</sup>lt;sup>26</sup> Zurich Role of Insurance in Society and Economic Development

http://zdownload.zurich.com/main/reports/What is the role of economic developement.pdf; http://www.zurich.com/internet/main/SiteCollectionDocuments/insight/social-and-economic-value.pdf <sup>27</sup> See Appendix 1 Zurich SRM brochure.

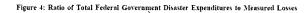
applied SRM TRP post-Sandy for a food supplier. Application of the TRP tool revealed that there was only one route through which a large portion of NYC food passes and the impact magnitude of the route interruption was great, so alternative route development proceeded to mitigate risk. Local governments and individual citizens may not have access to such information and may default to dependency on disaster recovery money rather than loss avoidance or mitigation through advance planning or investment.

Some may believe that *ex-post* disaster recovery funding takes the place of insurance. *Ex-post* disaster recovery funding is neither equivalent in function nor speed to private insurance <sup>28</sup>. One of the critical differences is that disaster recovery funds typically are delivered more slowly than insurance payments. The result is a slower recovery and even longer term negative economic impacts<sup>29</sup>.

Trends suggest some in society are now shunning private insurance because of the expected availability of government-funded disaster relief. The uninsured and underinsured are deciding to rely on perceptively lower cost *ex-post* financed disaster recovery mechanisms - but with concomitant lower economic functionality. This trend includes state and local governments in addition to individuals<sup>30</sup>.

This trend does not support economic resilience in the face of extreme events. In fact uninsured and underinsured economies are more likely to suffer long term macro-economic damage<sup>31</sup>. The financial reality of this ill-advised short term expense trade (e.g. avoiding premium payments) is long term negative economic productivity impacts<sup>32</sup>. Whether the asset

<sup>&</sup>lt;sup>28</sup> BIS Working Papers No 394, Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes by Goetz von Peter, Sebastian von Dahlen, Sweta Saxena, Monetary and Economic Department December 2012
<sup>29</sup> td.





<sup>31</sup> ld. BIS

<sup>32</sup> Id. BIS

owner has chosen public insurance with artificially capitated limits or disaster recovery mechanisms in lieu of private insurance, the impact of this choice does not often 'hit home', so to speak, until disaster strikes<sup>33</sup>.

A recent report prepared by the Insurance Information Institute and provided to the Federal Disaster Recovery Coordination Group confirmed that the substitution of private insurance with *ex-post* financed structures did not result in equivalent economic outcomes and provided the following observations<sup>34</sup>:

- (1) homeowners, renters and small business owners need to understand the importance of purchasing flood insurance. There also needs to be greater education about what is and is not covered under a flood insurance policy;
- (2) There was widespread confusion on the role of deductibles in an insurance policy and even more misunderstanding regarding wind and hurricane deductibles;
- (3) Homeowners and renters did not understand their overall coverage and their various insurance options;
- (4) Claimants need to have a better understanding of how the claims process works before there is a disaster; and
- (5) Some businesses did not understand their coverages either.

The above -cited report notes that individuals did not understand what was insured, uninsured and / or how disaster response funds might be available – or not – to help their personal recovery<sup>35</sup>.

Disaster aid is prioritized to address government function and services first; private assets are addressed as a secondary priority at best.

By contrast, insurance is a contract agreement governed by its terms, conditions and applicable law focused on the individual insured and their assets. Insurance is an on-going business, structured with *ex-ante* funds with a consistent administration in constant operation and procedures to assure efficient and timely administration to meet its obligations.

Disaster aid is generally episodic, unplanned and dependent upon *ex-post* special appropriations. Disaster aid must be distributed through a system which may be designed *ex-*

<sup>33</sup> http://www.wnyc.org/articles/wnyc-news/2013/apr/30/sandy-damage-prompts-some-to-walk-away-instead-of-stay/; http://news.yahoo.com/six-months-hurricane-sandy-much-still-175600302.html; and Id BIS.

<sup>34</sup> http://www.iii.org/assets/docs/pdf/Sandy-042413.pdf.

ante but which is only activated ex-post on an infrequent basis leading to concomitant start up delays.

The key strategic question is two-fold – can insurance play a role in accelerating the transition of insufficiently resilient-state assets to assets that meet underwriting criteria AND provide a stable, predictable, affordable risk management tool to society on a long-term basis?

Traditional insurance theory and proved applications suggest the answer is yes .

However, for insurance to play a substantial role in improving societal resilience to extreme weather events the following conditions must be in place: deployment of insurance must occur through collaborative public-private partnerships which address moral hazard mitigation and stem uncontrollable risk accretion by retaining the function of risk-based price signals to incentivize risk reduction on the part of risk creators.

Where net present value (NPV) mitigation investment opportunities exist with private insurance, deploying insurance would have *ex post* welfare enhancement value.<sup>36</sup> As one example, Zurich's work with Marriott has demonstrated the benefits of extreme weather event mitigation with minimal costs for wind protection and water resilience. "Upgrading to Zurich's HPR wind standard reduced the WIND PML (Probable Maximum Loss) potential by \$135 million," said Senior Risk Consultant Dale Seemans.

A major complication in assessing the welfare value of insurance is the interaction between four factors – increasing severity of the catastrophes, the rising trend of governmental aid, the substitution of government insurance for private insurance and the incentive of homeowners and the government itself not to mitigate<sup>37</sup>.

The real world value of the risk reduction incentive created by the *ex ante* insurance approach is significantly greater than the pure short-term cost efficiency offered by an *ex post* financing theory because it addresses what economists call moral hazard<sup>38</sup>.

Thus, by their very nature, private insurance and government sponsored disaster aid are different. Neither the power of private insurance nor government sponsored disaster aid can be fully leveraged in isolation. Maximum leverage of these resources arises only in cases of partnership and collaboration. This public-private partnership as discussed below is the only

<sup>&</sup>lt;sup>36</sup> Jaffe, Geneva Association papers., 2013 (1-26) Page 15 The Welfare Economics of Catastrophic Losses and Insurance, Dwight Jaffee and Thomas Russell identify four dependencies: insurable interest, "leaky bucket" frictional cost transfer inefficiencies for government disbursements, mandatory building codes commensurate with risk mitigation and other incentives for ex-ante risk mitigation.

<sup>&</sup>lt;sup>37</sup> Jaffe, Geneva Association papers., 2013 (1-26) Page 2 The Welfare Economics of Catastrophic Losses and Insurance..

BIS working paper 394; "A Vision for Managing Natural Disaster Risk, World Economic Forum April 2012, p 67.
 "A Vision for Managing Natural Disaster Risk", World Economic Forum April 2011 section 7.3.

way to leverage both activities to achieve long term, consistent resilience in the face of natural catastrophe, especially as exacerbated by climate change.

# Point 4: Government has a current and ongoing role in disaster preparedness and recovery that could be significantly enhanced through better collaboration with the insurance industry;

Government has an important and ongoing role in both disaster preparedness and disaster recovery. However, preparedness includes investments in pre-loss mitigation and regulation incentivizing prudent risk management behaviors on the part of communities.

Government should provide a systematic approach to risk reduction through national and regional plans that coordinate multiple stakeholders to bring about the necessary solutions <sup>40</sup>. Such plans need to be enabled by appropriate legislative and administrative frameworks which:

- Encourage and facilitate greater investment in pre-loss mitigation and improved infrastructure resilience;
- Promote and support transparent risk-based price signals;
- Address disadvantaged or at risk population with vouchers rather than hidden cross subsidy<sup>41</sup>;
- Promote and enable national minimum building codes and standards by conditioning federal matching funds on resiliency criteria;
- Clearly communicate priorities and limitations of disaster response and recovery so that citizens can make educated decisions about insurance and other risk management decision taking. 42

Current trends and studies suggest that more pre-loss mitigation expenditure would improve the return on the taxpayer investment in catastrophe-prone areas.

Governmental policies also need to be adjusted to achieve these ends. For example, building codes must be adjusted to be responsive to the extreme weather exposures of today and those

<sup>40</sup> Id.

<sup>41 &</sup>quot;Addressing Affordability in the National Flood Insurance Program", Issue Brief, Carolyn Kousky and Howard Kunreuther, jointly published by Resources for the Future and the Wharton Risk Management and Decision Processes Center, August 2013.

42 http://www.iii.org/assets/docs/pdf/Sandy-042413.pdf.

projected for the future, consistent with the expected useful life of the asset to be built or remodeled. This would assure that new and modified building stock was resilient during its expected useful life (upon which society relies for many economic calculations) and would leave only pre-existing building stock and assets as potentially inadequately resilient.

Such pre-loss mitigation expenses are exceptionally cost efficient providing a minimum of a 4:1 return on investment  $^{43}$ .

Insurance also can be leveraged to promote resilience in building. Insurers can require that assets be repaired or rebuilt after a loss event to the new sufficiently resilient building code. This approach "smooths in resilience" and assures that when the next extreme weather event strikes that the assets and communities are more resilient and less likely to experience repeat losses. This breaking of the cycle benefits residents, communities, governments, and business.

Point 5: There are immediate short term, medium term and long term actions that should be taken to close the resiliency gap, including but not limited to the promotion and enforcement of stronger building codes; promotion of investment in resilience; and support for and requirement of risk-based price signals.

Should resilience investment be prioritized over disaster response costs?

Absolutely. Why?

#### Investment in Resilience:

- 1. Saves Taxpayers billions of dollars annually this a cost effective investment that will save local, state and federal governments billions of dollars.
- 2. Provides greater protection to the public in the face of increasing extreme weather events, reducing human suffering.

<sup>&</sup>lt;sup>43</sup> Multihazard Mitigation Council (MMC), "NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities", National Institute of Building Sciences (2005).

- 3. Reduces business interruption and overall economic impacts of extreme weather events; and
- Creates domestic jobs and promotes domestic manufacturing in building more resilient housing and infrastructure

Studies affirm the value of pre-loss risk mitigation investment in reducing extreme weather and climate-related risk. In fact, one study claims a conservative 4:1 return on investment for risk mitigation (adaptation) investments<sup>44</sup>. Others have estimated a greater than 10 to 1 return so even 10% would be extremely valuable. Assuming the investments could ensure long term resilience, avoided losses should be discernible within a budget cycle reflecting the return rate of extreme events after completion of the first projects whether those projects are bricks and mortar or policy reforms - noting that the implementation of policy reforms may actually take longer in some cases than brick and mortar projects.

#### What should be done to improve resilience?

First, government could provide a systematic approach to risk reduction through national and regional plans that coordinate multiple stakeholders to bring about the necessary solutions 45. Adoption of a non-proprietary tool like the proprietary Zurich Total Risk Profile Tool would be beneficial. Before risk reduction strategy can be developed, a national priority plan must be developed. Much research about asset vulnerability exists, but a framework in which to evaluate and prioritize it does not. Development of this risk reduction prioritization framework, perhaps through the GAO may be a good vehicle for this.

Actions Congress could take to improve resilience might include:

- 1. Use the language of the Extreme Weather Title of the Water Resources Development Act as an example of what could be applied to improve the resilience requirements framing the hundreds of billions of dollars the federal government invests annually in water, port, highway, transit and aviation infrastructure.
- 2. Expand the Resilience Star pilot currently proceeding at DHS to include commercial applications and most importantly entire community resilience ratings. The IBHS Fortified Building Standard is integral to the Resilience STAR pilot. The Resilience Star initiative could be a game changer for dealing with community resilience. The pilot establishes the business case for becoming resilient and takes a return on investment

<sup>44</sup> Multihazard Mitigation Council (MMC), "NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities", National Institute of Building Sciences (2005).

45 "A Vision for Managing Natural Disaster Risk, World Economic Forum April 2012

approach. This approach should stimulate the market and create consumer demand for resilience. Individuals and businesses will realize benefits. This a a great example of a concerted collaborative public private effort to help build the Nation's resilience which should be expanded and supported. Given the interconnectedness of risks and impacts from extreme weather, extension of this currently limited residential home pilot to the improvement of entire community networks is essential to achievement of real extreme weather resilience. Through such an effort, the federal government could take a proactive leadership approach to promote the economic resilience of entire communities in the face of extreme weather.

Simultaneously, private and community resources should supply information on what individuals and communities can do to improve resilience. Regionally targeted assessments should be made to assess resilience of community, and resilience fact sheets should be prepared and distributed to insufficiently resilient populations. Given the combination of recent trends in drought and wildfire and the continued migration of greater populations to the wilderness urban interface (WUI), the need for this action will become increasingly urgent over time.

This information already exists in some cases, but in many cases it must be developed. Insurers have some information but by no means all if the information necessary to assess resilience needs and alternatives. Further, insurers do not develop this knowledge as part of their current business operations as many of these risks are not assumed by private insurers, but have been assumed by the government either through government insurance programs or by default as a disaster response provider.

Economic resources to perform such vulnerability assessments and for related responsive capital investments in resilience might be derived from the amount of special appropriations predicted by Cummins. It is also logical to take a portion of that predictable special appropriations demand and use it to improve resilience in assets.

#### How much should be budgeted?

From a practical perspective, funding resilience is a fundamentally wiser investment than spending on disaster relief and recovery. As previously noted, the Multihazard Mitigation Council found that funding resilience provides a 4:1 return on investment – reductions in future

costs of relief and recovery. Between 2011 and 2013, the US Government spent approximately \$136 billion USD on disaster relief and recovery <sup>46</sup>. If during this same three (3) year period the federal government had proactively budgeted and amount equal to 25% of those funds, approximately \$34 billion USD, and dedicated that amount to prioritize resilience investments, then approximately \$136 billion USD of future disaster relief and recovery costs could be avoided over the return rate of the extreme event cycle. As the incidence and costs to the federal government of extreme weather events increase so does the budget imperative to make greater investments in resilience.

Theoretically the determination of the appropriate amount for investment in resiliency should be based upon a technical assessment of a local and regional basis of vulnerability to extreme weather events, current resiliency conditions for vulnerable assets, and prioritization using a cost / benefit analysis framework. But, in the end, the amount of vulnerability that can be reduced will be bounded by the practical reality of the federal budget — and prioritization will need to be made with a temporal component.

Immediate, concrete and responsible actions, including increased capital investment in resilience is essential to maintain economic sustainability in the face of extreme weather events and climate change.

#### Conclusion

ZURICH believes that we have an opportunity to dramatically improve the resilience of our nation's homes, businesses and critical infrastructure and that this can be achieved in a manner that will ultimately save federal, state and local governments billions of dollars annually while providing citizens greater protection from extreme weather events. Seizing this opportunity will require:

- Extensive collaboration between the insurance industry and the federal government to provide needed incentives for improved resilience;
- Elimination of government policies and programs at the federal, state and local levels that provide perverse disincentives to improved resilience;
- Investment by local, state, and federal governments in enhanced infrastructure resilience measures;

<sup>&</sup>lt;sup>46</sup> "Disastrous Spending: Federal Disaster-Relief Expenditures Rise Amid More Extreme Weather", Daniel J. Weiss and Jackie Weidman, 29 April 2013 at <a href="http://www.americanprogress.org/wp-content/uploads/2013/04/WeissDisasterSpending-1.pdf">http://www.americanprogress.org/wp-content/uploads/2013/04/WeissDisasterSpending-1.pdf</a>.

Investment by businesses and homeowners in enhanced resilience measures

On the ground behavioral changes, shaped by government policies, in conjunction with increased investment in resilience and risk management must occur in order reverse the current trajectory of unbudgeted federal disaster expenditures. .

I hope my testimony has provided the Committee with a greater understanding of:

- (1) the economic value Zurich sees in resilience investments;
- (2) why Zurich believes more investments in improved resilience should be made today across regions of the nation with assets and people at elevated risk to extreme weather events; and
- (3) how Zurich thinks investments in improved resilience might be balanced with funding for disaster relief and recovery to maximize the economic impact of finite federal funds.

Zurich is extremely encouraged by the Committee's efforts to improve resilience and develop sustainable communities in the face of extreme weather events. Zurich looks forward to working with the bipartisan leadership of the Committee to perfect the innovative climate change adaptation tools of the future.



# A PART OF A STATE OF A

Reducing risks, leveraging opportunities









Over the last decade acts of terror, natural disasters, supply chain disruptions, cyber attacks and inancial crises have become part of the everyday occabulary of risk management. At the same time, compatities are striving to stay ahead in a highly competitive environment by undertaking activities that could involve high risks and potentially purt their future in danger. Implementing new business strategies – such as expanding into new product areas or geographic regions or acquiring new businesses – generates risks that companies need to identify and manage

in order to survive and prosper.

Dealing with risk goes beyond looking at a series of random events or mere risk-avoidance. To deal with risk properly means to look for strategic opportunities based on well-informed risk thinking.

In a 2011 Harvard Study\* sponsored by Zurich, ever two-thirds of 1,419 executives from companies around the world said that risk management had become either somewhat or significantly more important since the recession.

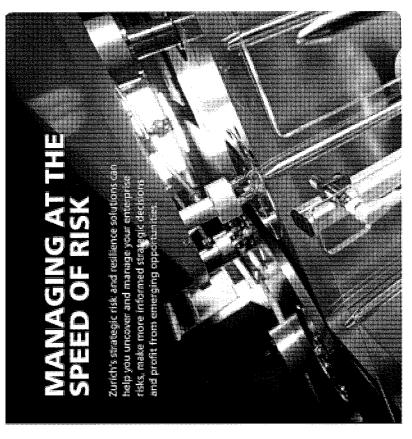
To help companies cope with today's risk warvonneut, its management thinking continues to evolve. Sound risk management demands an enterprice approach that addresses exposures and opportunities from all angles to increase the likelihood of aktieving organizational objectives and maximing strategic growth. Where risk management used to equate to buying insurance, it now encompasses a hotistic funancial and operational enterprise risks. And strategic risk management also means leveraging new growth opportunities.

A company that is better prepared to respond to unpredictable events – and to benefit from the opportunities that could arise – will have a major competitive advantage.

# THE CRUCIAL QUESTION TO ASK IS "WHICH RISKS, AND HOW MUCH RISK, SHOULD WE TAKE?"

\* Please visit www.zurichvir.com for a free copy of the study 'Risk Management in a Time of Global Uncertainty'

THE CRUCIAL QUE
AND HOW MUCH



Risk reaches all industries and geographies, and therefore demands broad anticipation and mitigation efforts in response. So it stands to reason that a major challenge – and success factor – in risk management can be a company's ability to link risk information to strategic planning and decision–making. This strategic approach can planning and decision–making. This strategic approach can planning and decision–making. This strategic approach critical exposures, and find that fine balance between the desire to grow and the necessity to manage risk.

An enhanced enterprise risk management framework can help you protect your profitability, reputation and stakeholder value. Zurich's strategic risk and resilience solutions are designed to bring you a broader view of your risks and an understanding of how these risks may affect your success.

# IMPROVING YOUR COMPANY'S APPROACH TO STRATEGIC RISK MANAGEMENT CAN:

- minimize barriers to achieving business objectives and maximize strategic growth opportunities
- generate superior business intelligence to enable more informed strategic decision-making
   decrease total cost of capital through increased risk transparency and optimizing the balance of
  - risk transparency and optimizing the balance of risk and opportunity including and entity key exposures, quantify critical activity and solidify value chains to enthance value creation and advantage.

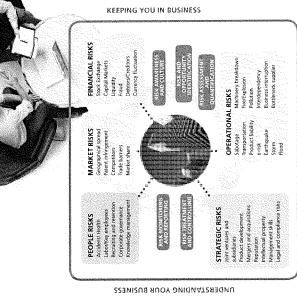


As an insurance company, we have nearly 150 years' experience in managing holistic risks for ourselves and our customers, making Zurich your ideal risk partner.

Zurich's strategic risk and resilience solutions go beyond delivering consulting services – we can help you to implement tisk management tools that empower you to better identify and manage the critical risks yourself. We can deliver a strategic approach to managing risks, supported by tactical solutions and tools.\*

Our Strategic Risk and Resilience Management resources are divided into two najor areas. Business Sevilience Services and Entepriers Risk Solutions, to office a broad set of innovative services that we can tailor to fit your unique business model and strategic challenges. We have a network of highly qualified professionals, based in different countries and drawn from many industry sectors, and will put together a tailored team of experts to best meet your needs.

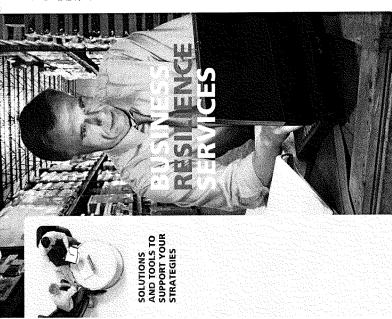
\*Some of the services referred to below are available only in specific regions. Please visit www.ZurichERM.com or contact your local Zurich representative for further details.



UNDERSTANDING RISK ACROSS YOUR BUSINESS

Zurich's Enterprise Risk Analysis (above) can highlight the many types of exposure you tace, from day-to-day operational risks to emerging risks and unexpected events.

5



The constantly changing risk landscape makes it difficult for companies to adequately prepare for business interruptions However, you can minimize the impact of both insurable and non-insurable interruptions by holistically assessing and addressing your organization's vulnerabilities. Zurich's approach to strategic risk and resilience management can help you by:

- providing a better understanding of your environment, key activities, dependencies and relationships
- quantifying the expected impact and extra expenses that disruptions could have on critical outputs
  - strengthening business continuity management and recovery efforts.

# ASSESS AND INSURE YOUR SUPPLY CHAIN RISKS

business resilience. Historically, supply chain disruptions lead to 9% lower sales and disruptions lead to 9% lower sales and 11% higher costs, and approximately 40% of companies with extended interruptions never recover. Zurich's suite of supply chain risk management tools can help you protect your profitability and build a major strategic advantage. The challenges of managing an increasingly complex network of suppliers can threaten

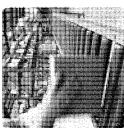
Our supply chain risk assessment can:

your organization's exposures to a wide range of risks including financial, deliver valuable input to understand regulatory, political, geographical, transportation and contract risks

- help you understand the potential impact and the cost of recovery from disruptions to your critical suppliers
  - provide action plans to help reduce or transfer supply chain risks.

Zurich's 'all risk' Supply Chain Insurance can cover supplies that are delayed or

tailored supply chain insurance can fill coverage gaps, and offers a pre-agreed claims process that improves transparency interruption and contingent coverages, which only activate as a result of a specified physical incident. Zurich's of extra recovery expenses. Our broad solution differs from typical business not delivered, and can even cover the potentially significant financial impact and settlement time.



### MODEL YOUR BUSINESS INTERRUPTION IMPACT

effects of possible interruption scenarios and interdependencies that may threaten business continuity. The software tool presents profit and loss exposure information for all disruptions in a single model to improve data management and interpretation, By uncovering and quantifying your largest profit exposures, business interruption modeling acts as a strategic link between risk management and financial management. especially when coupled with our supply chain risk assessment.

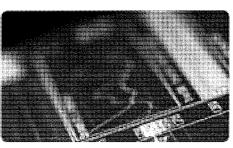


company from reactive to proactive, so that it's prepared to survive a disaster and return to normal operation as quickly and efficiently business continuity, we can help you identify threats against your company's operations and implement a response plan to minimize the negative impacts of a disruption to key business processes, mission-critical activities, and your value chain. A robust business continuity management strategy can move your as possible. With a team of experienced professionals certified in

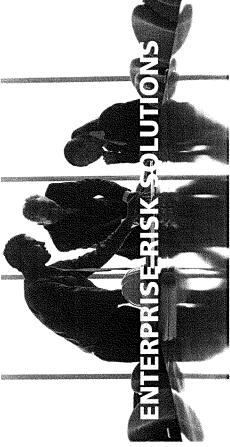












AND TOOLS TO
SUPPORT YOUR
STRATEGIES

TRATEGIES

YOU CAN'T MANAGE WHAT YOU CAN'T SEE, SO IT'S TO SUIPPISE THAT A STONG ENtERPRISE RISK MANAGEMENT (ERM)
PTCG179M IS A factor in increasing revenue and shareholder value.

A study by the Conference Board showed that companies with a robust ERM program had 59% increased profitability, 62% reduced earnings volatifity, and 86% cited ERM as helping them make better-informed decisions.

The current economic crisis places the need for enterprise risk management squarely in the enter and drives home the point that risk management must be anchored at the top. It also underscores the importance of an integrated approach to enterprise risk management that cuts through all layers or an organization.

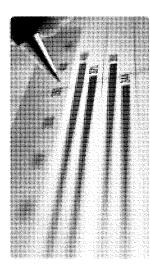
an oyes or an organization.
ERM can provide an active framework for uncovering
and understanding the many exposures that
threaten corporations' viability and capital efficiency.
Then, if the unexpected does occur, sound strategic

risk management will have contingency plans in place to make the organization more resilient.

ERM needs to address many different types of risk, from day-to-day operational risks to emerging exposures and unexpected events. We can work with you in a variety of customized ways to expand your RM risk culture and business intelligence. These include:

- understanding the gaps in the ERM program and how it can be enhanced
- deploying an effective strategic risk assessment process and integrating powerful risk insights to optimize the risk and reward balance
  - considering a purpose-built ERM software tool to support the process.

DO YOU WANT TO KNOW HOW YOU STACK UP AGAINST OTHER COMPANIES BASED ON AGGREGATED, ANONYMIZED DATA SOURCES AND WHAT STEPS YOU CAN TAKE TO IMPROVE YOUR ERM PROGRAM? OUR ONLINE TOOL AT **www.zurichus.com/zuricherM** CAN HELP YOU TO ASSESS TEN CRITICAL COMPONENTS.



### VALIDATE YOUR RISK MANAGEMENT FRAMEWORK

diagnostic service provides an effective gap analysis of your company's current ERM infrastructure, in order to drive the best next steps in increasing its effectiveness. The ERM diagnostic assessment will identify strengths and areas for improvement within your framework, to help you further embed ERM processes and yield greater positive outcomes. You can then dose the gaps in your ERM framework with step-by-step implementation support from Zurich's strategic risk Enterprise risk management (ERM) is a journey, and it's important to know how far along you are so you can continue in the right direction. Zurich's ERM management specialists.

## ASSESS YOUR HOLISTIC RISKS

To help you develop a more holistic approach to risk management, Zurich's Total Risk Prolifing (TR2) directs a systematic approach to addressing your organization's major exposures. TRP delivers a comprehensive assessment of business objectives, the associated challenges, and the mitigation strategy to help you identify, prioritize, and manage business risks across your enterprise.

assessing and managing the strategic risk associated with projects, mergers and acquisitions, We can modify TRP to suit the specific needs of each customer, ensuring that the core principles of good risk management remain. This flexibility makes TRP an ideal tool for and other key initiatives.

Zurich's own internal risk management process involves applying our proprietary TRP process to encourage analysis of a broad spectrum of risk, including asset liability management, investment, credit, brand and reputation, insurance and operational exposures.

ERM IN ACTION.

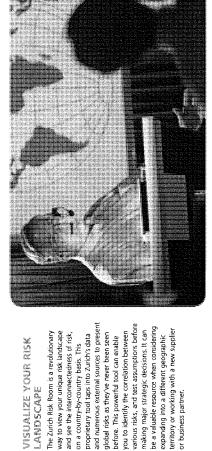
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VISUALIZE YOUR RISK LANDSCAPE

### and numerous external sources to present global risks as they've never been seen before. This powerful tool can enable various risks, and test assumptions before making major strategic decisions. It can be a valuable resource when considering The Zurich Risk Room is a revolutionary way to view your unique risk landscape and see the interconnectedness of risk, on a country-by-country basis. This you to identify the correlation between proprietary tool taps into Zurich's data SOLUTIONS AND TOOLS TO SUPPORT YOUR STRATEGIES

expanding into a different geographic



# AUTOMATE YOUR ERM EFFORTS

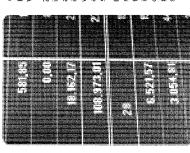
If you're looking to build or expand the effectiveness of your ERM infrastructure, Zurich's Velocity ERM software is a great place to start.

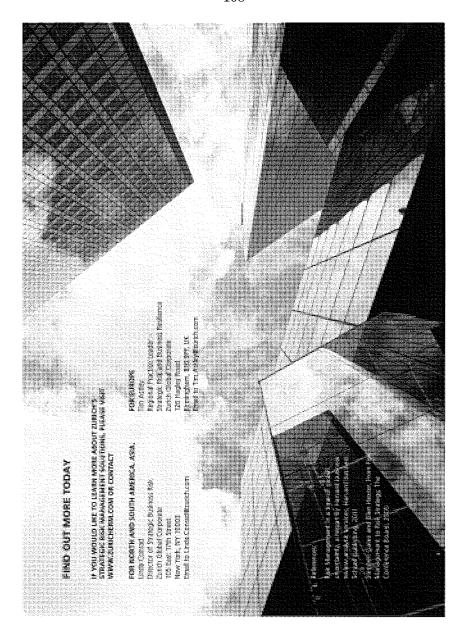
improve the way you identify and manage current and emerging enterprise exposures. Its power lies in its integrated, easy-to-use reporting capabilities, which produce real-time reports of your exposures Zurich's Velocity ERM software can help you to and mitigation, for inclusion in operational and strategic decision-making.

mix of risk transfer and other mitigation strategies, then measure and justify the resulting risk improvement through cost-benefit analysis, optimal explical allocation, risk aggregation / sorting / prioritization, risk correlation with business units, Its analysis capabilities let you determine the ideal scenario modeling vs. risk tolerance, and more.

While it is unlikely that you will ever be able to anticipate all extreme events precisely, you can mitigate their effects by trying to identify them in advance, and ensuring that robust risk management structures are in place to absorb them when they occur.

important part of capital efficiency and, ultimately, competitiveness. And this is where Zurch's strategic risk and resilience management solutions have a role to play. The effective management of both hazards and business risks has become an increasingly







The information in this publication was compiled by Zurich Services Corporation from sources believed to be reliable. We do not guidantee the accuracy of this information or any results and there as some no hability in convection with this publication, including any information, methods or safety suggestions contained bettern. Moreover, Zurich Services Corporation erremnds, you that this publication cannot be assumed to contain every exceptable safety and compliance procedure or that additional procedures might not be appropriate under the circumstance. The subject marter of this publication as well as any of the examingthe, which are given for pure illustrative purpose, therein are not ted to any specific insurance product nor will adobted these procedures insure coverage under any insurance policy.



Representing Electrical and Medical Imaging Equipment Manufacturers www.nema.org

### Statement for the Record by the National Electrical Manufacturers Association Hearing on "Extreme Weather Events: The Costs of Not Being Prepared" Committee on Homeland Security and Governmental Affairs United States Senate February 12, 2014

Chairman Carper, Ranking Member Coburn, Members of the Committee,

Severe weather events seem to be happening more frequently in the United States. Historic floods, tornadoes, hurricanes, and 2012's Superstorm Sandy have led to record levels of devastation and rebuilding. As we become more reliant on electricity to power our homes, businesses, industry, communications, and first responders, a more robust approach to electrical preparedness and recovery is critical to minimizing the personal and economic damage caused by these events.

To mitigate the impact of future weather events, the 400-plus members of the National Electrical Manufacturers Association (NEMA) and its staff of electroindustry experts have compiled recommendations in a guide entitled Storm Reconstruction: Rebuild Smart. This guide is available at no charge at www.nema.org/rebuild-smart.

NEMA is the association of electrical equipment and medical imaging manufacturers, founded in 1926 and headquartered in Rosslyn, Virginia. Its 400-plus member companies manufacture a diverse set of products including power transmission and distribution equipment, lighting systems, factory automation and control systems, and medical diagnostic imaging systems. Total U.S. shipments for electroindustry products exceed \$100 billion annually.

Federal, State, and Local Policies

Minimizing the damage caused by major storms requires an electrical grid that is built to be resilient and reliable before disaster strikes. As Storm Reconstruction: Rebuild Smart explains, deployment of smart technologies can make America's power systems safer, more reliable and resilient, and designed in such a way that they can be restored more quickly following a disaster. NEMA supports policies that encourage investment in smarter energy technologies to better protect lives, infrastructure, and communities:

- Review current public programs to ensure technologies that are reliable, resilient, and efficient
  are promoted;
- Promote policies to stimulate greater public and private sector investments in smart energy technologies such as incentives for U.S. industrial sector and the use of energy saving performance contracts (ESPCs) for state, federal, and local agencies;
- Authorize all federal storm reconstruction aid to be used for deployment of technologies that mitigate future power outages;

1300 North 17tb Street, Suite 1752 - Rosslyn, VA 22209 - 703.841.3200 - 703.841.5900 fax

- · Encourage routine adoption of the most current electrical safety codes in all states; and
- Promote adoption of an industry standard for equipment and structures in vulnerable areas.

### Risk Management Planning

Risk management planning should include deployment of smart technologies to mitigate future power outages:

- Engage experts in smart energy solutions to perform pre-crisis risk mitigation assessments;
- Create a unified emergency storm response plan to develop a cohesive blueprint for action that
  accounts for loss of power and damaged or fallen communication lines;
- Ensure that storm response plans are updated to utilize smart technologies for power restoration;
- · Invest in reliability testing and training for energy management systems.

### Technologies and Practices

The NEMA guide contains best practices, recommendations in energy systems design, development, and technology deployment that can reduce outages, save lives, and protect property:

- Smart Grid solutions, microgrids, energy storage, and distributed generation systems;
- · Alternative and backup generation technologies; and
- Advances in wiring, cabling, and components.

The NEMA guide and more information can be found online at http://www.nema.org/Storm-Disaster-Recovery/.

Thank you the opportunity to provide these remarks for the record. If you are interested in more information, please contact Kyle Pitsor, Vice President, Government Relations, at kyle.pitsor@nema.org or Charles Konigsberg, Vice President, Strategy and Policy, at chuck.konigsberg@nema.org.

nature climate change LETTERS

### Increasing stress on disaster-risk finance due to large floods

Brenden Jongman<sup>1\*</sup>, Stefan Hochrainer-Stigler<sup>2</sup>, Luc Feyen<sup>3</sup>, Jeroen C. J. H. Aerts<sup>1</sup>, Reinhard Mechler<sup>2</sup>, W. J. Wouter Botzen<sup>1</sup>, Laurens M. Bouwer<sup>4</sup>, Georg Pflug<sup>2</sup>, Rodrigo Rojas<sup>3†</sup> and Philip J. Ward<sup>1</sup>

Recent major flood disasters have shown that single extreme events can affect multiple countries simultaneously<sup>1-3</sup>, which puts high pressure on trans-national risk reduction and risk transfer mechanisms<sup>4-6</sup>. So far, little is known about such flood hazard interdependencies across regions<sup>7-8</sup> and the corresponding joint risks at regional to continental scales<sup>1-9</sup>. Reliable information on correlated loss probabilities is crucial for developing robust insurance schemes<sup>5</sup> and public adaptation funds<sup>10</sup>, and for enhancing our understanding of climate change impacts<sup>9,11,21</sup>. Here we show that extreme discharges are strongly correlated across European riverbasins. We present probabilistic trends in continental flood risk, and demonstrate that observed extreme flood losses could more than double in frequency by 2050 under future climate change and socio-economic development. We suggest that risk management for these increasing losses is largely feasible, and we demonstrate that risk can be shared by expanding risk transfer financing, reduced by investing in flood protection, or absorbed by enhanced solidarity between countries. We conclude that these measures have vastly different efficiency, equity and acceptability implications, which need to be taken into account in broader consultation, for which our analysis provides a basis.

Major river floods are typically driven by large-scale atmospheric circulations<sup>64,548</sup>. As a result, single flood episodes can affect vast areas in a short period of time, irrespective of economic and political boundaries<sup>14</sup>. This was demonstrated in June 2013 by the blocking of the planetary waves of the atmospheric floor regime in the Northern Hemisphere<sup>3</sup>, which led to extensive flooding and eastern Europe. Understanding the risk posed by large-scale floods is of growing importance, as their impacts are rising owing to socioeconomic development<sup>546</sup>, and their frequency and intensity may increase under a changing climate<sup>(8,11,27)</sup>.
Well-devised risk management of climate-related extremes, including floods, is therefore considered to be an important pillar

Well-devised risk management of climate-related extremes, including floods, is therefore considered to be an important pillar of climate adaptation!\*. Rising flood losses already force insurance companies to increase their capital base and may lead to more years of below-zero profitability. Uninsured risks are a growing concern, as a lack of financial means for rehef, recovery and reconstruction negatively affects the wellbeing of people, the economy and a country's budget\*19. Accurate information on the joint probability of flood losses that takes into account spatial correlations between river basins across different countries is essential for developing

insurance mechanisms and public compensation schemes to present and future extreme losses. This information is especially required and informative in the European Union (EU), where international disaster financing is increasingly connected through insurance regulations. I climate change adaptation strategies and a joint compensation mechanism between member states.

So far, methods for producing large-scale flood risk estimates have either been based on specific hazard event scenarios, or are upscaled from lower to higher spatial levels by summation of basin-level risk<sup>18-22-24</sup>. In both cases, natural correlation between events is neglected (that is, full spatial independence across river basins is assumed) and reliable estimates of extreme losses cannot be made. Hence, flood risk projections available to the disaster risk reduction community do not accurately represent geographical risk patterns and are not probabilistic in nature. We demonstrate here that natural dependencies among risks in different regions can be accounted for (Methods), and we present probabilistic projections of flood risk in the EU.

We find monthly peak river discharges in the 1,007 sub-basins to be a good proxy for the occurrence of reported damaging flood events!" on a European scale, as shown in Supplementary Fig. 1. The results show high positive cross-correlations in observed peak discharges between the river sub-basins in Europe, indicating a large degree of spatial interdependence in extreme river flows. Spearman's correlations are significant ( $\alpha=0.05$ ) in 63% of all sub-basins, and in 98% of the sub-basins showing strong correlations (that is, r>0.7; Supplementary Table 1).

Strong positive cross-correlations in peak discharge occur between basins in central and eastern Europe, following the patterns exhibited during the 2002 and 2013 floods across multiple countries in this region (Fig. 1a). Peak discharges in this area are often linked to the atmospheric circulation pattern Vb, or Genoa Low; that is, a low-pressure system travelling from the Atlantic southeast across the Mediterranean towards central Europe!. High-to-strong cross-correlations amongst southern European basins (Fig. 1b) are known to be caused by the occurrence of regular Mediterranean depressions<sup>24</sup>, whereas regional negative cross-correlations are also observed under the influence of Atlantic depressions<sup>35</sup>. We also find high-to-strong correlations in peak discharges amongst basins in western European countries, which have been linked to the occurrence of atmospheric rivers and extra-tropical cyclones<sup>3</sup> (Fig. 1c). On the basis of the peak discharge correlations, we assigned countries to 5 main regions, which are used for computing country-specific losses and the required compensation payments

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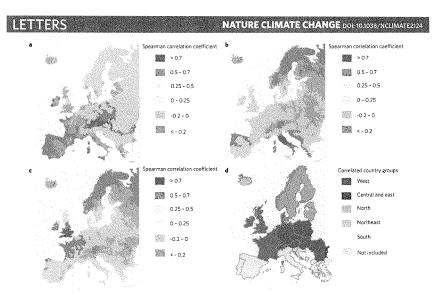


Figure 1 | Correlations of monthly peak discharges between basins in Europe. Spearman's rank correlation coefficient of extreme monthly discharges among European river sub-basins, calculated on the basis of LISFLOOD<sup>30</sup> simulations forced by observed daily climate data for the period 1990-2011 (Supplementary Fig. 1); Supplementary Table 2.) a-c. The correlations of all river basins with the basin contains the cities of Vienna, Austria (a); Rome, Italy (b); London, United Kingdom (c). d, We derived best estimates of aggregated natural discharge correlations between countries and identified 5 main regions of correlated extreme discharges. These regions are used to convolute probability distributions on an EU level and calculate country losses (Mathods).

(Fig. 1d; Methods). In this study, the correlations were computed over the entire time series for which discharge data were available (1990–2011; Methods). The results may vary depending on the selected time periods, because some of the atmospheric circulation patterns and resulting peak discharges show seasonal variation (Supplementary Fig. 2); and the circulation patterns, and hence rainfall distributions and intensities, may be influenced by climate changes "Matty". Uncertainty in these changes, however, remains high?"

rainfall distributions and intensities, may be influenced by climate change. \*\*MOV\*\* Uncertainty in these changes, however, remains high.\*\* Estimates of present and future potential flood damage (that is, damage that is expected if a flood event would occur) were computed using an ensemble of high-resolution climate simulations and projected gross domestic product (GDP) under the SRES A1B scenario (Methods), and thus include both climate change and socioeconomic development components. One of the main obstacles in estimating flood risk from potential damage on a continental scale has been the lack of aggregated information on flood protection standards maintained along rivers in different countries\*\*\(^{\text{MSI}\)\_{\text{MSI}\)\_{\text{MSI}\)\_{\text{T}}}}\) Existing studies assume either no protection\*\(^{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\)\_{\text{MSI}\)\_{\text{T}\)\_{\text{MSI}\}\_{\text{MSI}\}\_{\text{MSI}\)\_{\text{MSI}\}\_{\text{MS

We used the potential damage estimates, protection standards and peak discharge relationships to develop a joint probability distribution of flood losses in the EU (Methods and Supplementary Methods). We estimate expected average annual flood losses in the EU at €4.9 billion per year for the period 2000-2012, corresponding to reported average annual losses of €4.2 billion in the same period's, and show that these losses may increase to €3.5 billion by 2050 (Fig. 2a). Annual losses of the magnitude of the 2013 European floods ( $\sim$ 612 billion, or 0.1% of EU GDP; ref. 15) have a simulated expected occurrence probability of once in 16 years at present, and once in 10 years by 2050. Losses of this magnitude are projected to be below average modelled losses per year from 2030 onwards, mainly owing to rising losses from low-probability events. Under the SRES A1B scenario and the ensemble of climate change models we applied here (Supplementary Methods), about two-thirds of the modelled risk increase by 2050 is due to economic growth, and one-third due to climate change. The exact effect of climate change on rainfall patterns and the corresponding flood risk is still surrounded by significant regional uncertainties  $^{12}$ . Although we addressed these uncertainties to some extent by using an ensemble of climate models, the risk projections should be continuously updated as our understanding of climate change impacts on river discharges advances.

Empirical insurance penetration rates are used to estimate insured losses as a percentage of total losses across the EU (Methods). Assuming the present estimated insurance coverage (Supplementary Fig. 4) remains constant, average modelled insured losses per year are €1.6 billion (reported: €1.2 billion) for the period 2000-2012, increasing to €4.6 billion by 2050 (Fig. 2b). Total flood insurance claims with a once in 200 year probability, which is the stress threshold used to calculate legal minimum capital

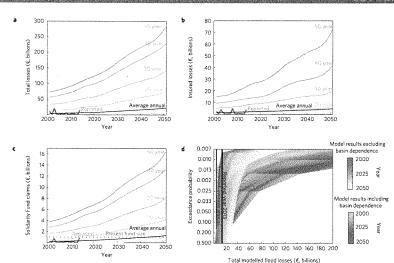


Figure 2 | Probabilistic projections of flood losses separated by financing source. Present and projected flood losses for different return periods in the European Union (EU-27) calculated using the probabilistic modelling framework (Methods). a-c, Total losses (a) are separated into: insured losses (b) and Solidarity Fund claims with a maximum present budget of E1 billion (dotted fline; c). d, The return periods (rp) represent statistical annual probabilities, with the annual exceedance probability given by 1/rp. Reported losses are derived from the Munich Re NatCatSERVICE database and include lower-bound estimates for the 2013 European floods. Incorporating the established spatial dependencies in risk assessment, as compared with assuming full independence between basins and countries, leads to higher overall loss estimates at lower probabilities (that is, it leads to a falt-tailed distribution).

requirements for insurers to avoid insolvency under the new EU-imposed Solvency II insurance regulations, are projected to increase from €116 billion in 2013 to €236 billion in 2050. In terms of uninsured risk, we estimate present annual average claims from flood risk to the EU Solidarity Fund (EUSF) at €258 million under the present guidelines (Fig. 2c). The present annual depletion risk, that is, the probability of claims exceeding the present fund size of €1 billion, is close to 5% and increases to 9% by 2050. Overall, mean uninsured losses for governments and households, after insurance and EUSF payouts under the present cover, are estimated at €3.3 billion per year in the period 2000–2012 (representing 67% of total losses: reported: €3.0 billion)³) and are projected to increase by a factor 4 by 2050, which is significantly higher than the projected

actor 2-9 growth of GDP.

Figure 2d shows that damage estimates from model runs incorporating the established basin dependencies (Methods; Supplementary Information) are higher than model results based on the traditional assumption of full spatial independence, especially for low probabilities (that is, the fat tail of the distribution). Furthermore, the graph shows that estimated probabilities of extremely low annual losses are also higher when we introduce basin correlations (that is, the likelihood of years with few disasters is higher). This result demonstrates the necessity of including correlations of peak discharges for understanding potential flood impacts at a continental scale. Changes in precipitation patterns could change the occurrence of floods<sup>1,1,1</sup> and it would be important to study effects on associated spatial correlations, as stronger correlations will result in more frequent and larger flood

losses, whereas a weakening of correlations would decrease the probability of losses.

Debate is ongoing at national and EU levels on how to best manage uninsured risk, and how to allocate the respective burdens between those at risk, the insurance industry and the wider society<sup>10</sup>. Among others, the increasing risks can be managed by pursuing a combination of measures aimed at increased insurance penetration; improving physical flood protection standards; and expanding the budget of the EUSF. To illustrate the effect of these measures on flood risk financing, we have defined six adaptation scenarios and computed their effects on flood losses, the details of which are provided in Supplementary Fig. 7 and Table 3. Higher insurance penetration rates can, in theory, be promoted at EU level by creating favourable tax regimes for building insurers' reserves; by mandatory flood insurance coverage in high-risk areas (possibly backed-up with government finance); or by furthering the integration of the European insurance markets<sup>21</sup>. If an average of 50% of total losses were insured across the EU (present penetration is 30% <sup>15</sup>), which is approximately the case in the 1 per 100 year floodplains in the United States<sup>5</sup>, the mean annual uninsured losses would be reduced by over €10 billion (approximately 60%) in 2050 (Fig. 3a). However, equity and insurance demand become important considerations if households are unable or unwilling to pay higher overall premiums<sup>21</sup>, which may increase more rapidly than expected losses (Supplementary Table 3).

losses (Supplementary Table 3).

As an alternative to broader insurance coverage, a larger part of losses could be shared amongst EU member states by increasing the size of the EUSF (ref. 10), which is capped at present at €1

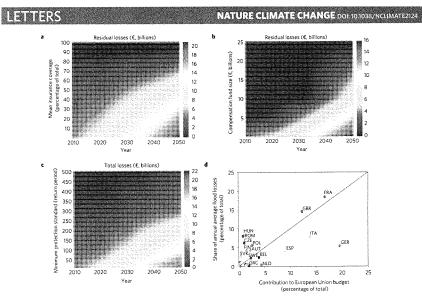


Figure 3 | Options for loss sharing and risk reduction, a,b, Reduction in modelled residual flood losses (that is, losses that are not insured and not covered by the EUSF) by: the implementation of a homogeneous mandatory insurance cover as a percentage of total losses (assuming the present EUSF; a) or by the EUSY Joy: the implementation of a nomogeneous manuality instructed cover as a percentage of control cover of the following the present part of the following the protection standards (Supplementary Fig. 3) to a legal minimum. d. Any compensation or adaptation financed from the EU budget will be subject to a distribution effect, depending on the relationship between the EU contribution and the flood risk of each country. In the long run, cross-subsidies are expected from countries with high EU contributions and low flood risk, towards countries in the opposite situation.

billion annually (Fig. 3b). As countries contribute to the fund relative to their overall contribution to the EU budget, however, cross-subsidizing will occur from countries with low flood risk relative to their contribution to countries with high flood risk (Fig. 3d)<sup>4</sup>. Given the fact that the EU holds solidarity among its core principles, there might be arguments for such a risk allocation, but the right balance between equity and market efficiency concerning the allocation of risk needs to be explicitly set out and negotiated. The possibilities for expanding the Solidarity Fund are mainly limited by EU budget considerations; compensating all flood losses would, at present, already consume more than 30% of the total EU budget, and would thus require an infeasible budget increase. The expansion of the EUSF is further constrained by justified concerns that the compensation mechanism might reduce national government responsibility and insurance incentives, and could thus he a disincentive (moral hazard) for risk reduction efforts<sup>10</sup>. We suggest it may be worth considering linking compensation by the EUSF to credible stronger efforts made by member countries to manage risk

manage risk.

Although disaster financing schemes are vital for sharing the abrupt financial burden of large floods, ex-ante investments in physical flood protection are an important means of reducing the magnitude of overall flood losses? Figure 3c demonstrates that increasing flood protection levels in all basins to a minimum of 1 per 100 years would decrease the total expected annual flood losses by around €7 billion (close to 30%) by 2050, and would got a grindful flood losses to 125 billion (close to 30%) by 2050, and would cost an estimated €1.75 hillion (Supplementary Table 3 and

Fig. 7). This emphasizes that the benefits of flood prevention will increase further as losses are projected to rise under climate change and socioeconomic development. Yet, physical flood protection measures also have considerable construction and maintenance measures also have considerable construction and maintenance costs (Supplementary Fig. 4 and Table 3), and the security they provide may lead to increased economic development in the protected areas, Given political will, financial capacities, differential abilities to absorb risk and many uncertainties particularly relating to climate change impacts, it is generally difficult to calculate an optimal level of protection for all EU countries, and decisions on the upfront investment in flood protection could focus on offering acceptable protection levels under the present and future climate.

Methods Potential flood losses for the period 2000–2050 for each of the 1,007 river basins were computed at a high (100 × 100 m) resolution using simulated daily discharge data, extreme value analysis, spatial inundation modelling, and an economic damage model, fillowing the method described in earlier work- $^{\rm LC}$ . The projections of flood hazard up to 2050 are based on LISFLOOD (ref. 30) simulations of three by an ensemble of 12 climate experiments derived from a combination of 4 general circulation models and 7 regional climate models' (Supplementary Methods). Both the climate change and economic development components of the flood and damage models were forced by the SRES-A18 scenario. Flood protection standards, defined as the minimum statistical probability discharge that leads to flooding, were modelled for each basin in three steps. First, minimum and maximum flood protection standards in the EU were estimated from literature study (Supplementary Table 2) at 1 per 10 years and

I per 500 years, respectively. A I per 1.000 years standard was manually assigned to The Netherlands. following the national flood defence levels in place there. Second, the EU-average flood protection was estimated by running the flood damage model with all hypothetical protection levels and analysing the intersection with reported losses. A flood protection standard ranging between the minimum and maximum was assigned to each basin as a function of the average potential damage per square metre; and in per 500 (basin with the lighest potential damage per square metre), and a separately assigned I per 1,000 level in The Netherlands (Simplementary Fig. 3). Modelled protection standards are thus higher in areas where the potential damages are high, owing to a relative concentration of people and assess, than in areas where potential damages are low. This is in line with policies in major Furopean river watersheds such as the Rhine and the Danube, where higher levels of protection are maintained in densely populated areas than in rural areas. The cubic interpolation over basins was calibrated using points of known flood protection (Supplementary Table 2). Flood protection standards were assumed constant over time for the projections presented in Fig. 2 (that is, the protection measures are assumed to be only upgraded to maintain the same failure probability under climate change, without further adaptation), and were increased to the new potential minimum standards in Fig. 3c (corresponding to the values on the y axis in this panel).

We combined the estimated optential damage with the modelled basin-level

this panel).

We combined the estimated potential damage with the modelled basin-level We combined the estimated potential damage with the modelled basin-level protection standards to derive probability loss curves for each year in which all modelled losses below the protection level were set to zero. We then used the peak river discharge time series to estimate natural dependencies between basin To account for nonlinearities in the dependency structure, we use the (flipped) Clayron copula C, (u, v), a specific copula from the Archimedean family:

$$C_n(u,v) = u + v - 1 + [(1-u)^{-s} + (1-v)^{-s} - 1]^{-1/s}$$

The Clayton copula provided sufficient flexibility in modelling dependencies given the data at hand (Supplementary Methods, Supplementary Figs. 5 and 6). This model was used to aggregate basis loss curves to the country level in a stepwise manner using the estimated copula parameters as the ordering criteria (Supplementary Methods). In more detail, the selection of the next basin to be (Supplementary Methods). In more detail, the selection of the next basin to be aggregated is based on maximizing the smallest tail dependency between the already selected basins and the potential candidates. This procedure avoids underestimation as well as overestimation of the risk. A stepwise conditional copula approach was adopted to estimate dependencies at the country level within the derived country groups (Fig. 1d): in the order of descending estimated pairwise Calyacon copula parameters  $\theta$ , the conditional copulas were used as stepwise extensions of the joint loss distributions. Between country groups independence was assumed. The conditional (flipped) Clayton copula with parameter  $\theta$  is given by:

$$C_n(u|v) = 1 - \left[ (1-u)^{-\theta} + (1-v)^{-\theta} - 1 \right]^{-(1+\theta)/\theta} (1-v)^{-(1+\theta)}$$

Finally, we computed 1 million random samples from the multivariate fluod loss model to calculate statistical loss probabilistics on a country basis, for each year in the time series. Expected average losses are correspondingly defined as the mean of all samples in the year of analysis. We factored intail modelled direct losses for each country by empirically estimated insurance coverage rates (Supplementary Fig. 4) to approximate expected average insurance payouts. Expected claims to the the EUSF were calculated from total estimated losses following the payout regulations governing this fund, which are based on the size of the damage relative to the national GDP and an arbitrary payout threshold!". Finally, we computed residual losses for instonal public and private sectors as the total flood losses minus insurance and Solidarity Fund payouts.

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### Author contributions

Author Contributions

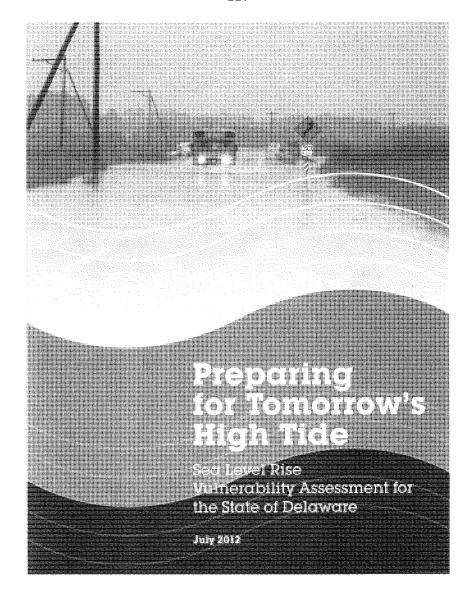
B. and P.J. we responsible for developing the protection standards methodology.

S.F.S., C.P. and B.J. developed the probabilistic upscaling approach. B.J. and S.H.S. computed the financing distributions and adaptation scenarios. R.R. undertonk the hydrological modelling and discharge correlation analysis. L.F. was primary responsible for modelling on potential damage. All authors, including J.C.H.R.L. IMB. R.M. and W.J. W.B., were involved in the conception and planning of the methods and analyses. in the writing of the outer. in the writing of the paper

### Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available unline at wave mature convergencie.

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### Other Documents in the Preparing for Tomorrow's High Tide Series

A Progress Report of the Delaware Sea Level Rise Advisory Committee (November 2011)

A Mapping Appendix to the Delaware Sea Level Rise Vulnerability Assessment (July 2012)

### Preparing for Tomorrow's High Tide

Sea Level Rise Vulnerability Assessment for the State of Delaware

Prepared for the Delaware Sea Level Rise Advisory Committee by the Delaware Coastal Programs of the Department of Natural Resources and Environmental Control

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### **About This Document**

This Vulnerability Assessment was developed by members of Delaware's Sea Level Rise Advisory Committee and by staff of the Delaware Coastal Programs section of the Department of Natural Resources and Environmental Control. It contains background information about sea level rise, methods used to determine vulnerability and a comprehensive accounting of the extent and impacts that sea level rise will have on 79 resources in the state. The information contained within this document and its appendices will be used by the Delaware Sea Level Rise Advisory Committee and other stakeholders to guide development of sea level rise adaptation strategies.

Users of this document should carefully read the introductory materials and methods to understand the assumptions and trade-offs that have been made in order to describe and depict vulnerability information at a statewide scale. The Delaware Coastal Programs makes no warranty and promotes no other use of this document other than as a preliminary planning tool.

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Further information about this document and the Delaware Sea Level Rise Advisory Committee can be found online at http://de.gov/stradvisorycommittee/ and at the address below:

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### **Executive Summary**

As a coastal state, Delaware's economy and quality of life have historically been linked to its shores, its vast expanses of protected tidal wetlands, and its fertile farm fields. Because of its location, low average elevation, and dependence on the coast, Delaware is particularly vulnerable to the effects of rising sea levels including loss of low-lying land and structures, saltwater intrusion into ground and surface waters, and increased coastal flooding from storm events.

Today, sea level rise is rarely, if ever, considered by governments, organizations, and individuals as they make decisions about where to develop, how to build, or what to preserve. However, changes in sea levels could impact the longevity, safety, and return-on-investment of projects that have long planning horizons or long life-spans. Accounting for changes in sea level that may be expected to occur over the lifetime of these projects will help lead to informed decisions for public and private investments by minimizing risk and potential for damage. Planning for the long-term effects of sea level rise may also help us better prepare in the short-term for flooding from coastal storms.

### Delaware's Sea Level Rise Advisory Committee

Delaware's Sea Level Rise Advisory Committee (SLRAC) was established by invitation of Collin O'Mara, Secretary of the Department of Natural Resources and Environmental Control (DNREC), to help the state plan for sea level rise. The committee is composed of members from a wide variety of interest groups including state agencies, local governments, citizen organizations, business organizations, and environmental organizations. The goal of the Sea Level Rise Advisory Committee is to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, business practices and make informed decisions.

The committee's work has been splif into two phases, a vulnerability assessment phase and an adaptation planning phase. This document is the culmination of the vulnerability assessment phase, during which the committee provided expert opinions to analyze and assess potential impacts of sea level rise to 79 statewide resources, ranging from roads to wetlands to tourism. This vulnerability assessment will be used as the basis for the next phase, adaptation planning. During the adaptation planning phase, the Advisory Committee will identify ways that government, businesses, and citizens can adapt their policies and business practices to reduce the impact of sea level rise on our state's citizens, economy, and natural resources. The final report of the Sea Level Rise Advisory Committee will contain recommendations to help governments, businesses and citizens prepare for sea level rise.

### Results of the Sea Level Rise Vulnerability Assessment

Delaware's sea level rise vulnerability assessment demonstrates that inundation from sea level rise will occur in all three of Delaware's counties, affecting a range of resources. Although the direct impacts from sea level rise inundation will be felt primarily in areas near tidal waters, every Delawarean is likely to be affected by sea level rise whether through increased costs of maintaining public infrastructure, decreased tax base, loss of recreational opportunities and wildlife habitat, or loss of community character.

Statewide, between 8% and 11% of the state's land area (including wellands) could be inundated by a sea level rise of 0.5 meters to 1.5 meters, respectively. Within those potentially inundated areas lie transportation and port infrastructure, historic fishing villages, resort towns, agricultural fields, wastewater treatment facilities and vast stretches of wetlands and wildlife habitat of hemispheric importance.



The St. Jones River meeting the Delaware Bay, southeast of Dover, Delaware

### **Executive Summary**

Based upon the information in this vulnerability assessment, the Sea Level Rise Advisory Committee ranked each resource according to the potential impacts that could result from sea level rise and their relative statewide importance. Based upon this ranking, 16 resources emerged as being of high concern statewide:

Beaches and Dunes. Delaware's coastline is an important ecological resource—providing habitat for a variety of plants, animals, insects, migratory birds, and a multitude of other terrestrial and aquatic wildlife. Shorelines naturally shift and retreat in response to wind, waves, tides, storms and rising seas. However, natural shoreline processes are interrupted by people's desire to live and recreate near the shore. Delaware's 381 miles of shoreline, including 24 miles that front the Atlantic Ocean, provides economic benefits from tourism, coveted high-value space for commercial and residential development, and many forms of recreation, including boating, fishing, and beach-going. When combined with wind-driven waves, sea level rise can exacerbate shoreline erosion that damages dune habitat and leaves infrastructure along the coastline vulnerable to storm damage. Beach replenishment has been the predominant means to offset sand loss and protect structures to which the state has contributed considerable funding. Due to the economic value, natural resource value and significant state investment in sand replenishment, this resource was ranked as a high concern.

Coastal Impoundments: Coastal impoundments are vital resources that serve to provide important breeding, migration, and wintering habitat for a variety of birds, serve as nurseries for fish, help to control mosquitoes, and provide important recreational opportunities. Impoundments in each county are at risk from sea level rise, A sea level rise of 0.5 meters would result in the potential inundation of 81% of the state's acreage of impounded wetlands. Up to 99% of all the state's acreage of impounded wetlands could be inundated at both 1.0 and 1.5 meters of sea level rise. The impacts will be relatively local; however the areas that are affected show high levels of inundation and complete loss of function. Since the majority of the resource within the state may be affected, this resource was ranked as a high concern.

Dams, Dikes & Levees: Between 39% and 78% of the state's 50 miles of dams, dikes and levees could be inundated by sea level rise by 2100. The highest concentration of potential impact is focused in Kent County, whose dikes primarily protect wildlife areas. The majority of the dikes in New Castle County protect people, properly, and, in one case, a contaminated site. These structures were built to provide a certain level of containment or protection. If a breach or structural failure were to occur, the resultant flooding could affect a large area inland of the structure. Due to these considerations, inundation of dams, dikes, and levees in the state was ranked as a high concern.

Evacuation Routes: Between 1% and 6% of the state's evacuation routes are within an area that could

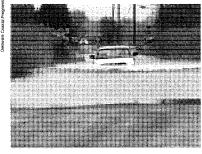


be inundated by sea level rise by 2100. Interstates and arterial roads tend to serve as the major evacuation routes for emergencies; substantial reliance on a single mode of transportation for evacuations may endanger many people if the highway infrastructure is made inaccessible because of sea level rise. All three counties experience exposure but the highest concentration is found in Sussex County. Because evacuations rely on automobile transportation and because flooded roadways can prevent or slow evacuation by car, inundation of evacuation routes was ranked as a high concern.

Freshwater Tidal Wetlands. Freshwater tidal wetlands occur at the upper reaches of estuaries where the water is no longer salty, but is still influenced by the rise and fall of the ocean tides. These wetlands are home to unique plant and animal communities and are known for their high species diversity. Sea level rise, over time, may introduce salinity to freshwater areas, replacing freshwater tidal marshes with brackish marshes or open water, which in turn will cause major shifts in species composition. For freshwater tidal marshes affected by sea level rise, a wetland system may still exist with increased salinity, but its unique habitat value will be lost. Sea level rise could impact between 84% and 95% of the total freshwater tidal wetland acreage statewide by the year 2100. Because of the unique habitats contained within freshwater tidal wetlands and because the majority of the resource within the state could be affected, this resource was ranked as a high concern.

Future Development Areas Between 3% and 7% of land designated as future development areas by Delaware's Strategies for State Policies and Spending are within an area that could be linundated by sea level rise by 2100. These areas are typically rural or suburban in nature and are adjacent to the actively growing zones of Delaware's municipalities. Four-lifths of these potentially inundated areas are located in Sussex County and could be developed to meet the future demand for residential and commercial development in and around the resort areas. Careful consideration must be given to determine whether directing new development to potential inundation areas will place citizens and infrastructure at risk in the future and whether creating new building restrictions will impact citizens' freedom of choice and the regional economy. Due to the significant potential effects for development in Sussex County coupled with the potential need for state funding of infrastructure repairs and legal concerns, sea level rise within future development areas was ranked as a high concern.

Habitats of Conservation Concern: The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identified 27 Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 unique habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure. Between 55% and 65% of the total acreage of the 15 HCCs analyzed could be inundated by sea level rise by 2100. Because these exceptional habitat types often harbor rare plant and animal species and are sensitive to environmental stresses, including sea level rise, this resource was ranked as a high concern.



 $\ensuremath{\mathrm{A}}\xspace$  driver navigates across a flooded road during a nor easter in October 2009.

### **Executive Summary**

Heavy Industrial Areas: Between 16% and 25% of the acreage of heavy industrial lands in the coastal area (as permitted by Delaware's Coastal Zone Act) are within an area that could be inundated by sea level rise by 2100; the majority of these areas are in New Castle County. While the inundation model shows that inundation risk to the facility buildings themselves is low, many associated structures like docks, piers, and lagoons could be affected. Because these facilities are a large economic driver for the state; reduced operational capacity could impact both the economies of the towns surrounding these facilities and the state's economy as a whole. If the lands currently zoned for heavy industry become unsuitable for industrial operations, retaining these businesses within the state could prove difficult due to lack of suitable industrially zoned land and the difficulties of rezoning land to industrial uses. Due to the significant potential statewide effects resulting from sea level rise, heavy industrial areas were ranked as a high concern.

Port of Wilmington: Between 36% and 73% of the Port of Wilmington's property is within an area that could be inundated by sea level rise by 2100. The port is based in northern New Castle County; however, the economic value to Detaware and the entire Northeast Region makes exposure to sea level rise a state and regional issue. Due to these considerations, inundation of the Port of Wilmington was ranked as a high concern.

Protected Lands Statewide. Protected lands encompass a variety of lands owned by state, local and municipal governments, conservation groups and individuals. These lands include state wildlife areas, state parks, state forests, boat ramps, nature preserves, historical sites, national wildlife refuges, municipal parks, open space, and recreational facilities and public and private conservation easements. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation. Statewide, between 37% and 44% of protected lands statewide are exposed to sea level rise under the three scenarios. Because these lands represent a significant investment to protect natural habitats and recreational use and because sea level rise could impact their intended use, protected lands were ranked as a high concern.

Roads & Bridges. Between 1% and 5% of the state's roads and bridges are within an area that could be inundated by sea level rise by 2100. Inundation of an individual segment of road could cause regional transportation disruptions, particularly if no alternative routes are available. The highest concentration of roadway exposure to sea level rise was found in Sussex County; however, potential exposure was found throughout the state. Due to the potential regional impacts, inundation of roads and bridges from sea level rise was ranked as a high concern.

Railroad Lines: Between 2% and 6% of the state's railroad lines are within an area that could be inundated by sea level rise by 2100. The highest concentration of impact is focused in New Castle County. Even with smaller amounts of exposure in Kent and Sussex Counties, it should be noted that if a single rail line segment becomes inundated, the entire functionality of the line could be lost. This may impact industries served by rail such as power plants and the Delaware City refinery. Passenger travel is also a concern; disruptions and possible restrictions to the Amtrak rail line could impact travel throughout the northeast corridor. Because disruption of rail service in Delaware ould have impacts throughout the state and region, inundation of railroad lines as a result of sea level rise was ranked as a high concern.

Tidal Wetlands: Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Tidal wetlands act as sponges by soaking up floodwaters and buffering storm impacts and also act as filters by trapping sediments and removing contaminants. The potential impacts to tidal wetlands as a result of sea level rise are striking in their extensiveness, affecting the vast majority of tidal wetlands in all three counties. The exposure assessment found that 97% of the state's tidal wetlands may be impacted at the 0.5 meter scenario, and 99% at both the 1.0 and 1.5 meter scenarios. Since the majority of the resource within the state may be affected, impacts to tidal wetlands as a result of sea level rise was ranked as a high concern.

Tourism and Coestal Recreation. Tourism and coastal recreation are important components of Delaware's economy and quality of life. Significant portions of Delaware's resort areas, coastal historic sites, and natural resources could be inundated or significantly altered by sea level rise. Of specific concern is the maintenance of Delaware's beaches, which are currently replenished on a routine basis with federal and state funding. Accelerated rates of sea level rise may necessitate larger or more frequent beach replenishment projects to preserve recreational beach uses. Due to the potential for revenue losses statewide, coupled with the potential increased funding needs for maintenance or repair of tourist destinations, sea level rise impacts to tourism and coastal recreation was ranked as a high concern.

U.S. Fish and Wildlife Service Refuges. Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton. Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and tourists use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for hunting and fishing. Refuge wetlands provide habitat for overwintering and migrating waterfowl and shorebirds, wading birds, secretive marsh birds and wetland passerines. Reduction or loss of wetland habitats within the protected boundaries of the refuges can impact populations of these species. Species may be forced to redistribute if refuge wetlands no longer meet their needs, and may relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation. Between 85% and 95% of refuge acreage could be inundated under the three scenarios. While the impacts are localized, the acreage affected (21,354 to 24,120 acres) represents a significant loss of protected habitat and was ranked as a high concern.

Wells: Residents and businesses in Kent and Sussex Counties rely on groundwater resources for drinking, irrigation and industrial purposes. Operation of wells that extract groundwater can be compromised by inundation from sea level rise, and the quality of groundwater can be compromised by saltwater intrusion resulting from sea level rise. Statewide, between 3% and 7% of domestic wells, 3% and 7% of industrial wells, 1% and 2% of irrigation wells, and 2% and 10% of public wells are within an area that could be inundated by sea level rise by 2100. Potential exposure of wells to sea level rise is focused along the coast; however, reduction in availability of groundwater in the coastal areas may increase demand on inland public wells. Because access to clean water is a necessity and because demand on inland wells may increase, sea level rise impacts to wells was ranked as a high concern.

The Sea Level Rise Advisory Committee will use the results of the Vulnerability Assessment to inform and focus efforts during the next phase of their work, the development of adaptation options.

### **Executive Summary**

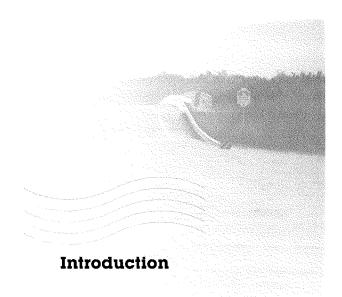
### Use of this Document

This document and its appendices provides an exhaustive accounting of resources vulnerable to sea level rise of up to 1.5 meters in Delaware. It includes background information, a description of the process used to assess vulnerability, exposure assessment tables, and risk assessments for 79 resources. A comprehensive set of vulnerability maps and information on how to use them is also included as the Mapping Appendix. The vulnerabilities and risk assessment described in this document should be considered as a starting point for more detailed localized or resource-based assessments and as a starting point for prioritizing adaptation strategies.

This document is the first of its kind to provide detailed estimates of numbers or acres of resources at risk from sea level rise at a state level. It represents a significant accomplishment and positions the state well to develop and implement specific adaptation strategies for resources most important to Delaware's continued sense of community, economic well-being, and natural resource diversity.



Homes and wildlife habitat at Broadkill Beach, along the Delaware Bay.



### Introduction

environmental organizations.

### Delaware's See Level Rise Advisory Committee

Delaware's Sea Level Rise Advisory Committee was formed to help the state plan for sea level rise, a coastal issue that could affect a wide range of quality of life and economic issues from infrastructure sustainability to crop yields to wildlife habitat. The committee was established by invitation of Collin O'Mara, Secretary of the Department of Natural Resources and Environmental Control (DNREC), to investigate Delaware's vulnerability to sea level rise and to provide recommendations about how to best prepare for higher sea levels. The committee is composed of members from a wide variety of interest groups including state agencies, local governments, citizen organizations, business organizations, and

The Sea Level Rise Advisory Committee held their inaugural meeting in November 2010 and has met thirteen times between November 2010 and May 2012. Three workgroups were formed in February 2011 to allow in-depth discussions of priority sea level rise issues: Natural Resources: Society & Economy and Public Safety and Infrastructure.

The committee's work was split into two phases, a Vulnerability Assessment Phase and an Adaptation Planning Phase. This document is the culmination of the Vulnerability Assessment Phase, during which the committee provided expert opinions to analyze and assess potential impacts of sea level rise to 79 statewide resources, from roads to wetlands to tourism. The vulnerability assessment will be used



The Delaware Sea Level Rise Advisory Committee

as the basis for the next phase, adaptation. During the Adaptation Planning Phase, the Advisory Committee will identify ways that government, businesses, and citizens can adapt their policies and business practices to reduce the impact of sea level rise on our state's citizens, economy, and natural resources. The final report of the Sea Level Rise Advisory Committee will contain recommendations to help governments, businesses and citizens prepare for sea level rise.

It is the intent of the Sea Level Rise Advisory Committee to provide information and guidance to help people make informed decisions when considering activities and investments in areas that may be at risk from the effects of sea level rise; it will not oversee implementation of adaptation measures. Any recommended adaptation action that would require a change in legislation or regulations will go through the normal legislative and public processes.

### Sea Level Rise Advisory Committee Member Agencies

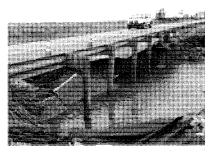
Delaware Association of Realtors	Delaware Office of the Governor
Delaware Department of Agriculture	Delaware Office of Management and Budget
Delaware Department of Health and Social Services	Delaware State Chamber of Commerce
Delaware Dapartment of Natural Resources and Environmental Control	Home Builders Association of Delaware
Delaware Department of Safety and Homeland Security	Kent County
Delaware Department of Transportation	League of Women Voters of Delaware
Delaware Economic Development Office	New Castle County
Delaware Farm Bureau	Positive Growth Alliance
Delaware Insurance Commissioner's Office	Sussex County
Delaware League of Local Governments	The Nature Conservancy
Delaware Legislature	Tidewater Utilities, Inc.
Delaware Nature Society	University of Delaware

### Planning for Sea Level Rise

Delaware is a coastal state; its economy and quality of life have historically been linked to its shores, its vast expanses of protected tidal wetlands, and its fertile farm fields. Because of its location, low average elevation, and dependence on the coast, Delaware is particularly vulnerable to the effects of rising sea levels including loss of low-lying land and structures; saltwater intrusion into ground and surface waters; and increased coastal flooding from storm events.

Today, sea level rise is rarely, if ever, considered by governments, organizations, and individuals as they make decisions about where to develop, how to build, or what to preserve. However, changes in sea levels could impact the longevity, safety, and return-on-investment of projects that have long planning horizons or

long life-spans. Accounting for changes in sea level that may be expected to occur over the lifetime of these projects will help lead to informed decisions for public and private investments by minimizing risk and potential for damage. For example, expensive retrofits or replacements of roads and buildings could be avoided by building structures that are specifically designed to withstand a certain rise in sea level. Funding and resources for shoreline stabilization, wetland restoration, and infrastructure improvements could be planned and in-place before emergency measures are necessary. Thoughtful, proactive planning for sea level rise may help Delaware's economy and natural resources continue to flourish even with the new long-term challenges sea level rise brings.



The impacts of storm surge from Hurricane Irane in August 2011 take a toll on State Highway Route 9 over Augustine Creek near Port Penn, Delaware.

Planning for the long-term effects of sea level

rise may also help the state better prepare in the short-term for periodic flooding from coastal storms. Storm surges of between two and four feet frequently occur along the Delaware Bay and Atlantic coast from tropical storms and nor'easters. Delaware's largest storm on record, a nor'easter that occurred in 1962, caused a storm surge of 4.5 feet (1.4 meters) in Lewes; a nor'easter that occurred on Mother's Day in 2008 produced a storm surge of 4.0 feet (1.2 meters) in Bowers Beach. These storm surges are comparable to the sea level rise expected by 2100; any actions taken to reduce the effects of sea level rise in the future will also have the added benefit of increased protection from storm surge flooding now.

The goal of the Sea Level Rise Advisory Committee is to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, business practices and make informed decisions.

### Introduction

### Effects of Sea Level Rise

Sea level rise is just one of the factors that contribute to changes in the coastal landscape over time. Other factors such as storms, erosion, and sediment accretion act in concert with changes in sea level to shape the size and makeup of our sandy shorelines, wetlands, and river channels. However, as the rates of sea level rise accelerate, sea level rise may increasingly become the driving force in coastal changes. Accelerated rates of sea level rise could cause inundation of low-lying land, saltwater intrusion into groundwater and streams, and increased extent and severity of storm flooding.

Inundation of low-lying land and structures can occur when the sea level rises faster than natural forces can build up land or where shoreline protection structures are not constructed. This can cause dry land to become flooded and can cause wetlands to convert into open water (CCSP, 2009). Structures, including homes, roads, and utilities that have been built in low-lying areas can become difficult to access, suffer structural instability or become unusable. This vulnerability assessment focuses primarily on these inundation effects in Delaware.

Saltwater intrusion of groundwater and streams can also occur as sea levels increase. In rivers and streams, sea level rise may cause the "salt line" to move inland, changing the types of vegetation in and around the stream, and impacting the quality of fish spawning areas. It also may affect intake structures for drinking water and industry. In certain areas, water from the ocean and bay may turn groundwater supplies sally, affecting water used for drinking and irrigation (United States Environmental Protection Agencey & Delaware River Basin Commission, 1986). The data and information necessary to assess the potential for saltwater intrusion issues from sea level rise in Delaware is not currently available, however, throughout this document, potential impacts are discussed, and data gaps are highlighted.

### Salt Line

The salt line is the location where a stream or river is no longer considered to be salty (contains less than 250 milligrams per liter of chloride). The salt line fluctuates each year depending upon tidal inputs and freshwater inflows from rain and dam releases. In the Delaware River, the salt line is currently a mile south of the Delaware Memorial Bridge, but has reached as far as 2 miles north of the Ben Franklin Bridge in Philadelphia in severe drought years.

As sea level rises, flooding from coastal storm events may become more widespread. As sea levels increase, so do the storm surge' heights generated by a given storm. An increased storm surge height, combined with resulting coastal erosion and loss of tidal wetlands that provide natural flood protection may result in increased flood depths in already flood-prone areas. It may also cause flooding in areas further inland that have not previously been flood-prone. Flooding from storm surges can cut off evacuation routes and cause significant damage to homes and infrastructure.

While increased storm surge heights and flooding is a very important consideration for understanding the potential range of effects caused by sea level rise, modeling specific storm surge impacts statewide is a complicated and resource-intense undertaking that was outside of the scope of this assessment. However, the general effects of increased storm surge heights with regard to resources of concern are discussed throughout this document.

Figure 1 maps shoreline retreat in the Bombay Hook area of Delaware Bay. This map demonstrates historic shoreline loss along the shoreline of Bombay Hook Delaware and was constructed using shoreline maps for 1883 and 1969 published by the National Ocean Service, and a digitized shoreline from a US Geological Survey aerial photograph taken in 2007. Rates of shoreline retreat at this location between 1883 to 2007 range from 2 to 5 meters per year. Between 1969 and 2007, the rate was 5 to 10 meters per year, among the highest rate for the wetland coast of Delaware Bay. A combination of storm-wave erosion and relative sea level rise are responsible for landward migration of the shoreline over time (CCSP, 2009).



Figure 1 - Shoreline erosion (Woods Hole Group Consulting, Inc.)



Dockside parking lot at Bowers Beach in May 2009 after a nor easter.

Storm surge is an abnormal rise of water generated by a storm. A useful description of storm surge can be found on NOAA's website http://www.nhc.noaa.gov/surge/

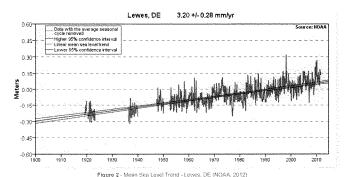
### Introduction

### Rates and Causes of Sea Level Rise

Sea level trends are recorded by tide stations, which measure the height of water referenced to a stable point on land with a known elevation (benchmark). Tide stations are primarily installed for navigational purposes and their data are used to make tide predictions. Long term data sets from these tide stations have also been used to understand local and global sea level trends (IPCC, 2001). Globally, sea level rises for two primary reasons: expansion of saltwater as it warms and loss of ice on land. As the ocean absorbs solar radiation in excess of what it emits, the water warms. When water warms, it expands and causes the average level of the water to rise. In addition, as the Earth becomes warmer, land-based glaciers and ice-caps melt and sidle into the sea. This melt-water and ice empties into oceans and causes the average level of the water to rise. In combination, these two forces constitute the eustatic (or global) rate of sea level rise<sup>2</sup>. The eustatic sea level rate during the twentleth century, as determined by tide gauge measurements, was about 0.07 inches per year (or about 7 inches over 100 years) (IPCC, 2001).

Tide gauges indicate that the change in the local mean sea level (LMSL)<sup>3</sup> in Delaware is greater than the eustatic sea level rate. The rate of change recorded at the tide gauge in Lewes is 0.13 inches per year (or 13 inches over 100 years), as compared to eustatic rate of 0.07 inches per year. This difference is due to the vertical movement of the Earth's crust, which is causing the land in Delaware to slowly sink. Tide gauges record this combined motion of the land and the sea. Figure 2 shows the local mean sea level trend from the tide gauge at Lewes from 1919 to 2011. Other tide gauges throughout the Mid-Atlantic show similar trends\*.

While it cannot be proven with certainty, climatologists have predicted that the rate of sea level rise occurring today will likely become greater in the decades to come (IPCC, 2001) The extent of the increase will depend on a number of factors including future emissions of greenhouse gases (especially carbon dioxide), the rate at which the temperature of the ocean increases and the rate at which fice is lost from land-based glaciers.



The eustatic sea level rate is a technical term for the worldwide change of sea level elevation with time \*Local Mean Sea Level (LMSL) is a term that describes the height of the ocean relative to land, measured hourly by a tide gauge and averaged over a inviteer eyer proof known as the National Tidal Datum Epoch

#### Future Rates of Sea Level Rise

In 2009, the DNREC formed a Sea Level Rise Technical Workgroup to provide the Department with planning scenarios for sea level rise to the year 2100. This workgroup, composed of scientists from the University of Delaware, Delaware Geological Survey, Center for the Inland Bays, Parlnership for the Delaware Estuary and DNREC, reviewed historical data for local sea level rise and reviewed the findings of international and national sea level rise expert panels. Based on this information, the Sea Level Rise Technical Workgroup recommended three planning scenarios for sea level rise to 2100. The conclusions of the workgroup were then reviewed by national experts<sup>9</sup> and used by DNREC in the development of an internal policy that directed it to plan for sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009).

The Technical Workgroup chose to recommend a range of scenarios to DNREC because it is not possible to precisely predict future rates of sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009). The three scenarios can be used as a planning tool to determine a range of potential outcomes and options. The Technical Workgroup's low scenario was a sea level rise of 0.5 meters (1.6 feet) between now and the year 2100. This scenario is slightly higher than the current rate of sea level rise in Delaware and is partially based on low estimates for future global

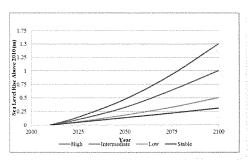


Figure 3 - Sea Level Rise Scenarios Recommended by DNREC's Technical Workgroup.

warming. The high scenario was a sea level rise of 1.5 meters (4.9 feet) between now and the year 2100. This scenario is based on higher estimates of future global warming. The intermediate scenario was 1.0 meter (3.3 feet) between now and the year 2100, and is based on moderate estimates of future global warming. Figure 3 contains a graph of the three scenarios, which can be used to estimate a range of sea level rise scenarios between now and 2100. The upward curvature of the lines indicates that the rates increase with time. The straight, or "stable," line is included for reference; it shows the sea level that would occur if today's rate of sea level rise continued into the future, rather than accelerating.

These three scenarios were provided to the Sea Level Rise Advisory Committee by DNREC and have been used throughout the vulnerability assessment to understand the potential range of impacts that sea level rise may have for the state. Evaluation and endorsement of these recommended sea level rise scenarios was outside of the purview of the Advisory Committee.

It is important to note that scientists are continually working to increase their knowledge about sea level rise and to provide better predictions of future sea levels. As new data and information become available, the planning scenarios (and associated maps) will be revised in order to reevaluate potential impacts.

<sup>&</sup>quot;Tide gauge information is available from the National Oceanic and Atmospheric Administration: http://tidesandcurrents.noaa.gov/sitrends/sitrends.shtml.

<sup>&</sup>lt;sup>o</sup>The scenarios were reviewed by S. Jeffress Williams, Coastal Marine Geologist at the US Geological Survey Woods Hole Science Center and Jim Titus, US Environmental Protection Agency

## Introduction

#### Visualizing Sea Level Rise

It is difficult to reliably model how shorelines and coastal areas will change and reshape due to the combined forces of accelerated rates of sea level rise, coastal erosion, storm surges and human activities (dredging, shoreline protection), particularly at a statewide scale. However, bathtub inundation models, which assume a static shoreline, can be useful in identifying low-lying coastal areas that could be subject to inundation in the future.

Using high resolution elevation data, a bathlub model of the state was created. The bathlub model floods all land below a certain elevation, unless there is a structure that would block tidal flow (like dikes and dams). Based upon this model, a series of maps was developed to show what the recommended sea level rise scenarios would look like on the ground at mean higher-high water (see lext box). Maps were created for mean higher-high water (MHHW), MHHW + 0.5 meters, MHHW + 1.0 meter and MHHW + 1.5 meters.

### Mean Higher High Water (MHHW)

These sea level rise scenario maps depict potential future sea levels at mean higher-high water, a term that describes an average height of water at high tide, in Delaware, there are two high tides per day. Of those, one rises slightly higher than the other (the same is true of low tides). Mean higher-high water is calculated by taking the average of the higher of the two high tides each day, observed over a nineteen year period (the National Tidal Datum Epoch).

The maps are available online as an interactive viewer at http://de.gov/slrmap.aspx. A complete description of the process used to develop the maps is available in the Mapping Appendix document.

There are many other terms used to describe water levels at various tides (e.g. mean high tide, ordinary high water mark)6; in this document any time the term "high tide" is used, it is referring to mean higher-high water.

These maps show the level of high tide in Bowers Beach, Delaware under three different planning scenarios, which were developed using local data coupled with scenarios generated by several federal agencies.



Bowers Beach at high fide, 2011

Bowers Beach at high tide with 1.6 feet of sea level rise

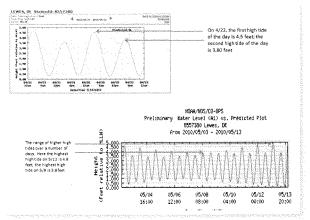


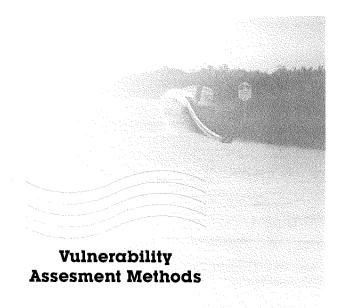
Figure 4 - Differences in high tide heights.



Rowers Beach at high tirle with 3.3 feet of sea level rise

Bowers Beach at high lide with 4 9 feet of sea level rise

\*A useful reference that briefly describes water level recording devices and tidal datums is available online from the Southeast Atlantic Coastal and Ocean Observing System (SEACOOS): http://seacoos.org/Data%20Access%20and%20Mapping/water\_level\_product\_desc



# Vulnerability Assesment Methods

Vulnerability assessments are conducted as a way to understand the effects of a hazardous event, whether the event is an attack by a computer hacker, a tornado or in this case — sea level rise. Vulnerability assessments identify locations and extent of impacts and often prioritize the importance of these impacts. This process can then lead to changes that may limit the negative effects should the event occur.

Completion of a statewide vulnerability assessment for sea level rise was the first major task of the Sea Level Rise Advisory Committee and represents a significant achievement. Delaware is the first state to comprehensively assess specific resource vulnerability to sea level rise at a statewide level. This document provides detailed information about what resources will be impacted, where those impacts will occur and what the likely secondary social, environmental, and economic effects will be. Because the vulnerability assessment has a very large scope and covers a large geographic area, it should be considered a screening tool for determining the need for more detailed vulnerability assessments and for development of sea level rise adaptation strategies.

#### The Vulnerability Assessment was developed in five stages, described in detail below:

- 1. Identification of Resources of Concern
- 2. Data Collection
- 3. Exposure Assessment
- 4. Impact Assessment
- 5. Risk Assessment

Additionally, a series of Public Engagement Sessions was held to inform the public of the Committee's activity and as a cross-check on the issues



House raised above coastal flood zone in Slaughter Beach. Delaware,

# Identification of Resources of Concern

Each workgroup met several times to identify issues that would result from sea level rise and to identify specific resources of concern to them. The definition of resource in this case is broad, including items from historic sites to industrially zoned land to roads to special wildlife habitats. As a result of these discussions, the three workgroups identified 140 resources that could be mapped and quantified for use in the vulnerability assessment.

#### Data Collection

In order to conduct an in-depth vulnerability assessment, geographic datasets are necessary. Geographic datasets are a special type of dataset that contains information so that it can be placed on a map. Delaware Coastal Programs staff spent considerable time and effort compiling geographic datasets that could be utilized with the sea level rise scenario maps to determine the location and numbers of resources at risk from sea level rise. Datasets like roads, railways and public safety facilities were relatively easy to obtain as they are maintained and routinely updated by a state or county agency. Many datasets were out of date or lacked appropriate documentation as to when the data was collected or how it was collected (metadata). A few datasets were unable to be used for this assessment due to privacy or homeland security concerns (electrical substations for example). In many other cases, the desired data did not exist or was so out of date that it could not be used.

Of 140 datasets identified as necessary to understand impacts to resources, 79 were obtained and analyzed as a part of this vulnerability assessment. In all cases, existing data was used for this assessment. Creating, improving or updating geographic datasets generated by disparate entities was outside of the scope of this assessment. However, throughout this document, all data sources are cited and any issues with the data are explained. Additional information about this is available in the Mapping Appendix.

#### Exposure Assessment

After the data was collected, an exposure assessment for each resource was conducted using ArcGIS. Locations of resources of concern were "overlaid" with the three sea level rise scenarios; any resource within the sea level rise scenarios was counted as "exposed." Figure 4 shows how this was done using storage tanks as an example. The pink dots represent locations of storage tanks; the vellow areas indicate areas that could be inundated at the 1.0 meter sea level rise scenario. Any pink dot within the yellow area would be counted as exposed at 1.0 meter. Results are reported in an Exposure Table and summarized for each scenario and for each county (see Table 2 and text box description of how to use the exposure tables below). Maps were also developed for each resource that depict the geographic extent of inundation under each scenario at a statewide level (see Mapping Appendix for complete description of how statewide maps were developed and how to interpret them).

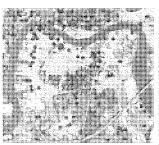


Figure 5 - Storage tanks exposed to inunitation.

The exposure tables and maps are an indication of the extent and severity of inundation for a specific resource. However, a resource that is "exposed" to sea level rise may or may not be impacted. The impact of this exposure depends upon a number of factors including whether a building is elevated or flood-proofed; the type of materials utilized in construction; or use of protective structures. For example, a home that is within a mapped sea level rise area (and therefore "exposed") but is raised on pilings may not suffer any structural damage from increased water levels. Conversely, there are also instances where resources may be affected but are not included in the exposure table. For example, structures which are not incundated but are surrounded by inundation areas become "islands" and may no longer function as intended because of access issues.

# Vulnerability Assesment Methods

#### Impact Assessment

Using the information obtained in the exposure assessment, committee members provided input about the potential direct impacts that could result from the inundation of resources as well as the secondary economic, environmental, and social impacts that could result.

#### Direct impacts include

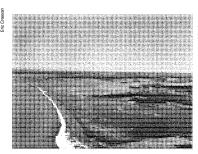
- . Loss of land and wetlands from inundation
- · Loss of buildings and infrastructure from inundation
- Decreased usability of structures due to flooded access roads and supporting infrastructure
- Increased structural damage from repetitive storm damages

#### Secondary impacts include

- · Loss of jobs and revenue streams
- · Loss of community or sense of place
- Contaminant releases from industrial sites or storage tanks
- Loss of habitat from increased erosion• Increased need for government services or intervention

Because this assessment was conducted at a statewide scale, all "exposed" resources were assumed to be impacted. Vulnerability assessments can be conducted in the future that focus in on a geographic area or specific resource; limiting the scope of a vulnerability assessment allows for more site specific conditions to be considered. This statewide vulnerability assessment should be considered a screening tool to determine where more focused studies should be conducted.

Information for each resource compiled in a standardized format and reviewed by workgroup members and Delaware Coastal Programs staff. The individual assessments (including exposure tables) are included in the remaining chapters of this document.



The community of Kitts Hummock next to the Delaware Bay

#### Public Engagement

A series of five public engagement sessions was held in November 2011 to share preliminary results of the exposure and impact assessments with Delawareans and to obtain feedback about the findings and work of the committee. Additional information about public engagement strategies can be found in Appendix E.

#### Risk Assessment

The final step of the vulnerability assessment was a risk assessment exercise that considered the combined consequences of the sea level rise exposure and impacts documented for each resource. Using standardized questions, workgroups ranked each resource according to the statewide magnitude of potential impacts. The magnitude of impact was determined using three primary factors: the geographic scope of exposure, the geographic scope of impacts and the functionality of the resource.

In considering geographic scope of exposure, the workgroups used the vulnerability assessment maps to determine where inundation would occur. For geographic scope of impacts, the workgroups considered where direct or secondary impacts would occur. Would impacts be felt by citizens statewide, or in a limited area? Would exposure cause economic impacts to one neighborhood, or would it cause impacts statewide? For example, although the exposure of heavy industrial areas was limited primarily to New Castle County, the economic impacts of exposure could be felt statewide through loss of job opportunities and revenues.

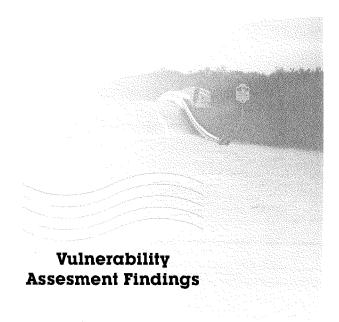
In considering functionality, the workgroups determined whether a resource could continue to meet its intended purpose when exposed to sea level rise. For example, an evacuation route functions to allow safe travel in emergency situations; a manufacturing facility functions to produce goods and provide jobs; a wetland functions to provide wildlife habitat and to attenuate storm flooding.

As a result of this discussion, each resource was ranked as a High, Moderate, Low, or Minimal Concern. In general, resources of high concern are those that if inundated, no longer meet their intended use and this loss of function would have statewide implications. Resources of low concern are those that, if inundated, would likely continue to function with modifications and whose impacts are generally of localized concern. Resources ranked as a high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

This risk assessment was subjective in nature; workgroup members used the information available to them to make a reasonable assessment of the risk to the state for inundation of each resource. The risk assessment will inform Phase II (adaptation) of the SLRAC's work. Adaptation strategies for many of the resources ranked as high and moderate concern will be discussed and developed, however, that does not preclude the development of strategies for resources that were ranked as lower concern at this time.

Table 1 - Risk Assessment Scores, Basis and Recommended Action

Score	Impact		Geographic Scope	Recommended Action
High Concern	Resource does not function or meet its intended use	And/or	Statewide	Develop adaptation strategies
Moderate Concern	Major loss of function or some failure of intended use	And/or	County-level	Evaluate further and develop adaptation strategies if necessary
Low Concern	Resource functions with modifications	And/or	Localized	Monitor and re-asses in future years
Minimal Concern	minor or no impact to function	And/or	Isolated	Re-asses in future years



## Vulnerability Assesment Findings

This vulnerability assessment demonstrates that inundation from sea level rise will occur in all three of Delaware's counties, affecting a range of resources. Although the direct impacts from sea level rise inundation will be felt in areas near tidal waters, every Delawarean is likely to be affected whether through increased costs of maintaining public infrastructure, decreased tax base, loss of recreational opportunities, or loss of community

Table 2 - Total Acreage of Uplands and Wetlands Exposed to Sea Level Rise

Land Area												
County	Total Acres		res Inundated SLR Scenario			rcent of Tota d by SLR Sc						
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m					
State	1.385,495	110,497	133,531	151,528	8%	10%	11%					
New Castle	278,754	25,179	29,916	33,148	9%	11%	12%					
Kent	510,428	50,095	57,784	63,269	6%	11%	12%					
Sussex	596.314	35.223	45,831	55.111	6%	8%	9%					

Source: USGS and Delaware Geologic Survey, State Outline (Aren), 2007-04-01

Statewide, between 8% and 11% of the state's land area (including wetlands) could be inundated by sea level rise of 0.5 to 1.5 meters. Table 2 shows potential inundation by acreage and percent of land area for the state as a whole and for each county. The county with the lowest percentage of land area at risk is Sussex County, where between 6% and 9% of the land area could be inundated by sea level rise. This may be a surprising result to many, and emphasizes the statewide nature of the sea level rise issue.

The nature of resources at risk varies between counties. The vast majority of the land area that could be inundated within Kent County is tidal wetlands, although the surrounding uplands and communities would also be affected. Wetlands are also affected in southern New Castle County, but in the northern parts of the County several urban residential and commercial areas are at risk, as are transportation corridors, including the Port of Wilmington. In Sussex County, low lying resort communities along the Atlantic Ocean, Delaware Bay, and Inland Bays are within potential inundation areas, as are tidal wetlands in the Inland Bays and Delaware Bay areas.

#### How to Use the Exposure Table

Exposure tables are provided throughout this document to help the reader understand the number or acreage of a resource that could be inundated by 0.5, 1.0 or 1.5 meters of sea level rise and to help the reader understand where those potential impacts occur. Maps are also provided in the Mapping Appendix to assist the reader to visualize the geographic extent of potential inundation.

The "Total Acres" column in Table 2 represents that total area of the state or county. The "Acres Inundated" columns report the number of acres of land that fall within the three sea level rise scenarios. These numbers are reported cumulatively. For example, 151,528 acres of land statewide would be inundated at 1.5 meters of sea level rise; this includes the 133,531 acres of land inundated at 1.0 meter.

The Percent of Total Inundated columns provide an additional way to understand the extent of inundation. The percent is calculated by dividing the Acres Inundated by the Total Acres. Because the Acres Inundated column is reported cumulatively, the Percent Inundated column is also cumulative.

#### Results of Resource Risk Assessment

As outlined above, the SLRAC workgroups conducted an exercise to determine the relative level of concern for impacts to each resource assessed. The results are below and are detailed further in the following chapters.

High Concern - A high concern resource is generally a resource where inundation would cause it to no longer function as designed and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruptions in jobs or revenue streams. Additional research and development of adaptation strategies for high concern resources is strongly recommended.

The following resources were ranked as high concern by SLRAC workgroups:

Heavy Industrial Areas	US Fish & Wildlife Property	Port of Wilmington
Future Development Areas	Railroad Lines	Tourism and Coastal Recreation
Roads and Bridges	Tidal and Freshwater Tidal Wetlands	Beaches and Dunes
Evacuation Routes	Coastal impoundments	Dams, Dikes & Levees
Habitats of Conservation Concern	Wells	Protected Lands Statewide

Moderate Concern - A moderate concern resource is generally one in which there is some impact or loss of function and/or the geographic extent of the impact is less than statewide. Further evaluation and development of adaptation strategies for moderate concern resources is recommended.

The following resources were ranked as moderate concern by SLRAC workgroups

The tellething receptage from thinkes	do moderate concern by our rio war	ngroups.		
Residential Areas	Landfills, Nature Preserves	Septic Systems		
Agricultural Land Conservation Easements	Wastewater Facilities			

Low Concern - A low concern resource is generally one in which the impacts to the resource itself would not be significant or/or the impact would be isolated to several small geographic regions. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts would not be of statewide concern. Low concern resources should be monitored and reassessed in subsequent planning activities.

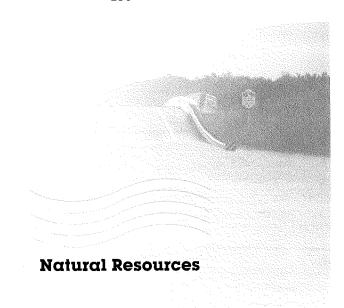
Businesses and Commercial Areas	Brownfield Sites	Agriculture
Salvage Yards	Historic and Cultural Resources	Underground Storage Tank Sites
Factories	Contaminated Sites	Non-tidal Wetlands
Commodity Pipelines	Highly Productive Agricultural Soils	Agricultural Land Preservation Districts

Minimal Concern - A resource of minimal concern is generally one in which the geographic scope is isolated and/or would have minor to no loss of function. Minimal concern resources should be reassessed in subsequent planning activities.

Upland Forest	Bus Routes and Bus Stops	Adult and Child Care Facilities	
Emergency Services	Cemeteries	Navigation Aids	
Schools	Boat Ramps and Piers	Leaking Underground Storage Tank Sites	

No Exposure - The following resources were analyzed and were found to have no exposure to sea level rise of up to 1.5 meters.

/			
Correctional Facilities	Public Safety Access Points	Airports	
Cell Towers	Hospitals		



#### Assessing Exposure of Natural Resources

The Natural Resources Workgroup was composed of members of the Sea Level Rise Advisory Committee and additional subject matter experts. A list of those who participated in this workgroup is available in Appendix C. The workgroup met six times between Fabruary 2011 and March 2012 to identify, assess, and rank issues related to environmental impacts from sea level rise.

#### Resources Considered

Specific resources that the Natural Resources Workgroup was concerned with included:

- Water resources (such as salinity changes and groundwater effects)
- Wetlands
- · Beaches and dunes
- · Upland forest
- Flora and fauna
- Protected lands
- · Agricultural resources such as soils and protected lands

#### Assessing Exposure

As described in the introductory section, Delaware Coastal Programs staff worked with Workgroup and Committee members to collect data and information about each resource that the workgroup wished to assess. Based upon available data, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. All of this information was compiled together into a comprehensive assessment for each resource, which were reviewed and edited by workgroup members. Full text of each one of

#### Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a state level screening of resources at risk to sea level rise. In some cases, data and information that would have provided a better picture of the resource impacts of sea level rise was not available at a scale that would be useful for analysis of sea level rise. However, this did not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts. Two resources in particular, Salinity Changes and Groundwater Effects, were difficult to assess given the unknowns about the complex hydrological and hydrogeological interactions involved. The potential impacts are discussed within the natural resources chapter however; there is not enough data to compare the level of concern about sea level rise impacts relative to the other resources.

Beaches and Agricultural resources were also densified by the Society and Economy Workgroup as a concern but were evaluated from a different. perspective. Whereas this workgroup was more flousated on endogical subjections of the resources, the Society and Economy Workgroup review of beaches concentrated more on tourism and recreational uses. For agriculture, the workgroup reviewed total acreage and types of agriculture for economic and cultural impacts. Salinity Changes: The influence of sea level rise on salinity levels in rivers and streams depends on the increase in tidal prism and the increase in estuary surface area (its width), assuming the tide range remains unchanged. The mean depth of the estuary will increase with sea level rise only if sedimentation does not keep pace with the vertical space created. The extent to which the tide range changes with sea level rise (if at all) depends on the modified depth and width of the estuary, which is difficult to predict given the number of variables involved. For this reason it is problematic to forecast how the salinity of estuarine waters will change with sea level rise, independent of other factors such as climatic changes in freshwater runoff and human influences on the geometry of the basin.

Groundwater Effects. Rising sea levels could increase the salinity of groundwater tables in shallow coastal aquifers. As rising water levels submerge low-lying sections of land, portions of the aquifer could become saline. Aquifers recharged by fresh water regions of the Delaware River may become saline in the future as well, if salt water pushes further up the waterway. The inundation scenarios used to assess resources affected by sea level rise are ill-suited to provide a meaningful assessment of potential groundwater impacts. Hydraulic interactions between sea level, aquifers, precipitation, streams, and other surface waters are too complex to draw conclusions based on just the increase in water level assumed in the three scenarios.

#### Assessing Vulnerability of Natural Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Natural Resources Workgroup conducted an exercise to assess the vulnerability of the state to the effects of sea level rise for each resource. Using standardized questions, the workgroup considered the two primary factors: the geographic scope of impacts and whether the resource could continue to "function." For geographic scope, the workgroup considered both the discrete locations of impacts themselves and the extent to which impacts may be felt outside of those locations. For example, loss of lands protected for wildlife habitat not only affects the species that live there but may also reduce ecotourism opportunities and generated revenue. As a result of this discussion, each resource (with the exception of Salinity Changes and Groundwater Effects discussed above) was ranked as a high concern, moderate concern, or low concern. Resources ranked as high and moderate concerns will likely become the starting point for adaptation strategy development in

#### High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: tidal wetlands, freshwater tidal wetlands, coastal impoundments, habitats of conservation concern, protected lands statewide, U.S. Department of Fish and Wildlife property, and beaches and dunes. A high concern resource is generally a resource where inundation would cause it to no longer provide its typical functions, values, benefits and/or could cause impacts statewide. Additional research and development of adaptation strategies for high concern resources is recommended.

<sup>&#</sup>x27;The tidal prism is the volume of water that moves into and out of the estuary during a tidal cycle

<sup>&</sup>lt;sup>2</sup>The tide range is the vertical difference between the high tide and the low tide

Tidal Wetlands: Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Tidal wetlands act as sponges by soaking up floodwaters and buffering storm impacts and also act as filters by trapping sediments and removing contaminants. The potential impacts to tidal wetlands as a result of sea level rise are striking in their extensiveness, affecting the vast majority of tidal wetlands in all three counties. The exposure assessment found that 97% of the state's tidal wetlands may be impacted at the 0.5 meter scenario, and 99% at both the 1.0 and 1.5 meter scenarios. Since the majority of the resource within the state may be affected by sea level rise, this resource was ranked as a high concern.

Freshwater Tidal Wetlands: Freshwater tidal wetlands occur at the upper reaches of estuaries where the water is no longer salty, but is still influenced by the rise and fall of the ocean tides. These wetlands are home to unique plant and animal communities and are known for their high species diversity. Sea level rise, over time, may introduce salinity to freshwater areas, replacing freshwater tidal marshes with brackish marshes or open water, which in turn will cause major shifts in species composition. For freshwater tidal marshes affected by sea level rise, a wetland system may still exist with increased salinity, but its unique habitat value will be lost. Sea level rise could impact between 84% and 98% of the total freshwater wetlands acreage statewide by the year 2100. Because of the unique habitats contained within freshwater tidal wetlands and because the majority of the resource within the state could be affected, this resource was ranked as a high concern.

Coastal impoundments: Coastal impoundments are vital resources that serve to provide important breeding, migration, and wintering habitat for a variety of birds, serve as nurseries for fish, help to control mosquitoes, and provide important recreational opportunities. Impoundments in each county are at risk from sea level rise. A sea level rise of 0.5 meters would result in the potential inundation of 81% of the state's acreage of impounded wetlands. Up to 99% of all the state's acreage of impounded wetlands could be inundated at both 1.0 and 1.5 meters of sea level rise. The impacts will be relatively local; however the areas that are affected show high levels of inundation and complete loss of function. Since the majority of the resource within the state may be affected, this resource was ranked as a high concern.

Habitats of Conservation Concern. The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identified 27 Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 unique habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure. Between 55% and 65% of the total acreage of the 15 HCCs analyzed could be inundated by sea level rise by 2100. Because these exceptional habitat types often harbor rare plant and animal species and are sensitive to environmental stresses, including sea level rise, this resource was ranked as a high concern.

Protected Lands Statewide. Protected lands encompass a variety of lands owned by state, local and municipal governments, conservation groups and individuals. These lands include state wildlife areas, state parks, state forests, boat ramps, nature preserves, historical sites, national wildlife refuges, municipal parks, open space, and recreational facilities and public and private conservation easements. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation. Statewide, between 37% and 44% of protected lands statewide are exposed to sea level rise under the three scenarios. Because these lands represent a significant investment to protect natural habitats and recreational use and because sea level rise could impact their intended use, protected lands were ranked as a high concern.

U.S. Fish and Wildlife Service Refuges: Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton. Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and tourists use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for hunting and fishing. Refuge wetlands provide habitat for overwintering and migrating waterfowl and shorebirds, wading birds, secretive marsh birds and wetland passerines. Reduction or loss of wetland habitats within the protected boundaries of the refuges can impact populations of these species. Species may be forced to redistribute if refuge wetlands no longer meet their needs, and may relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation. Between 85% and 95% of refuge acreage could be inundated under the three scenarios. While the impacts are localized, the acreage affected (21,354 to 24,120 acres) represents a significant loss of protected habitat and was ranked as a high concern.

Beaches and Dunes: Delaware's coastline is an important ecological resource—providing habitat for a variety of plants, animals, insects, migratory birds, and a multitude of other terrestrial and aquatic wildlife. Shorelines naturally shift and retreat in response to wind, waves, tides, storms and rising seas. However, natural shoreline processes are interrupted by people's desire to live and recreate near the shore. Delaware's 381 miles of shoreline, including 24 miles that front the Atlantic Ocean, provides economic benefits from tourism, coveted high-value space for commercial and residential development, and many forms of recreation, including boating, fishing, and beach-going. When combined with wind-driven waves, sea level rise can exacerbate shoreline erosion that damages dune habitat and leaves infrastructure along the coastline vulnerable to storm damage. Beach replenishment has been the predominant means to offset sand loss and protect structures to which the state has contributed considerable funding. Due to the economic value, natural resource value and significant state investment in sand replenishment, this resource was ranked as a high concern.

#### Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup, Nature Preserves and Agricultural Land Conservation Easements were categorized as having moderate concern. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impact is less than statewide.

Nature Preserves: Nature preserves are relatively undisturbed protected lands, free from development pressure and thereby provide exceptional habitat for various species of flora and fauna. These lands are unique and often fragile environments that represent some of Delaware's most important natural habitats. The percentage of affected acreage of dedicated nature preserves ranges from 34% to 43% under the three scenarios. The impact to the resource appears to be fairfy local in scale; however, the habitat value of those sites may be exceptional. As a result of these factors, impacts to nature preserves from sea level rise were ranked as a moderate preserv.

Agricultural Land Conservation Easements. The Delaware Department of Agriculture has a land preservation program that uses two strategies to preserve farmland, agricultural preservation districts (ranked low concern and discussed below) and agricultural conservation easements. Conservation easements provide permanent protection from development for agricultural activities. Statewide, 13% to 17% of the land in conservation easements may be exposed to rising water. The exposure is localized with a concentration in Kent County. Conservation easements are considered to be an important tool to preserve farming operations and to prevent development and infrastructure in vulnerable areas. Due to these considerations, impacts to conservation easements were ranked as a moderate concern.

#### Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Non-tidal Wetlands, Highly Productive Soils, Agricultural Land Preservation Districts, and Upland Forest. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather the impacts will not be significant in nature and/or will be isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Non-tidal Wetlands. Non-tidal freshwater wetlands are floodplains of natural stream channels, ditched modifications and extensions of natural streams, and isolated systems. These wetlands represent a large proportion of the forested area in Delaware and are too wet to build upon or farm without substantial draining or filling. These wetlands are classified as emergent, shrub or forested systems. When all three types are combined, 8% to 12% of the total non-tidal wetland acreage throughout the state is potentially affected under the inundation scenarios. Under the right conditions these wetlands may become tidal, thereby maintaining some of their former functions. This conversion will however, affect the uniqueness of the non-tidal wetland habitat. Given the relatively limited acreage affected, impacts to non-tidal wetlands from sea level rise were considered a low concern at this time.

Highly Productive Soils. This resource includes soil types considered to be prime farmland and farmland of statewide importance. Prime farmland is land whose soils have the best combination of physical and chemical characteristics for the production of crops. Farmland of statewide importance includes those soils that are nearly prime farmland and that produce high yields of crops when treated and managed according to acceptable farming methods. Land classified as having highly productive soils includes some areas that are not currently used for agriculture. Statewide, impacts to highly productive soils are limited, with 2% to 4% of the highly productive soils potentially exposed under the three scenarios. Localized impacts may be significant but would not negatively affect the state as a whole. As such, impacts to highly productive soils were ranked as a low concern at this time.

Agricultural Land Preservation Districts: The Delaware Department of Agriculture has a land preservation program that uses two strategies to preserve farmland, agricultural preservation districts and agricultural conservation easements. An agricultural preservation district is a voluntary agreement to use land only for agricultural purposes for at least a ten year period. There is no guarantee that the property will remain agricultural land once the 10 years expires but there is the possibility of permanent protection under the conservation easement program. Approximately 8% to 11% of acreage within Delaware's agricultural land preservation districts will be exposed to sea level rise. Because the acres affected is not a large percentage of the acres within the preservation districts program statewide, this resource was ranked as a low concern at this time.

Upland Forest: The level of exposure to upland forest resources is fairly limited. The combined impacts from the three upland forest types—deciduous, evergreen and mixed forest—range from 2% to 6% for the state as a whole under the range of inundation scenarios. Reductions in upland forest will negatively affect biodiversity and wildlife habitat, including that for migratory bird species. However, given the relatively limited acreage affected, impacts to upland forest from sea level rise were considered a low concern at this time.

#### Detailed Resource Assessments

The following sub-chapters contain a detailed exposure assessment for each resource and a description of the likely economic, social and environmental impacts that could result. As discussed in the introduction to this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

#### Water Resources

This section of the vulnerability assessment focuses on two primary concerns related to sea level rise with respect to water resources: the effects of changes in salinity within the Delaware Estuary and Inland Bays and the impacts to groundwater from salt water inundation. Neither issue is easily addressed as there are many unknowns. In order to evaluate the potential impact from sea level rise more information is needed, including an evaluation of the potential for intrusion of saltwater further into the Delaware River and Inland Bays and a detailed evaluation of the freshwater heads in coastal aquifers to identify potential changes in the salt content in coastal aquifers.

#### Salinity Changes

The salinity regime of a waterbody determines not only human uses, such as drinking water or agricultural irrigation, but also regulates habitat suitability for aquatic plants and animals. It also impacts certain aspects of water quality and flow dynamics.

Estuaries of coastal Delaware receive fresh water from rivers and saline water from the coastal ocean. In general, the salinity of estuarine waters reflects a balance between the freshwater discharge volume and the tidal prism volume. For example, fresh water enters the Delaware River and Bay estuary primarily through the Delaware, Schuylkill, and Brandywine/Christina river tributaries. Salt water is driven into the bay between Cape May and Cape Henlopen at its mouth by a combination of tidal currents and non-tidal density-driven flow. Fresh water is less dense than salt water, so freshwater runoff tends to flow over the salt water transported landward from the mouth. These waters mix with tidal energy, a process that leads to a transition from salt water at the bay mouth to fresh water in the upper estuary.

At any point along an estuary, salinity levels vary as a result of tides, storms events, and seasonal cycles in precipitation and evaporation. Over a long period of time, processes that alter the freshwater discharge or tidal prism influence the steepness of the along-estuary salinity gradient and the mean salinity of the estuary as a whole. Such a change could result from changes in weather and climate patterns and oceanographic phenomena, among other factors.

The landward limit of salt in surface water, also known as the salt line, is based on established drinking water standards of 250 milligrams per liter chloride concentration. The Delaware River and Basin Commission uses the seven day average location of the salt line to define the upper bounds of salinity intrusion in the Delaware Estuary. The salt line varies daily in response to tides, seasonally and in response to freshwater inputs—rainfall, streamflow, and reservoir releases—but is typically between Wilmington, Delaware and Philadelphia, Pennsylvania.

Exposure to Sea Level Rise: With rising mean sea level, an estuary will widen through erosion or submergence of its coasts, particularly in low-lying areas. The influence of sea level rise on salinity depends on the unit increase in tidal prism with unit increase in estuary surface area, assuming the tide range remains unchanged. The mean depth of the estuary will increase with sea level rise only if sedimentation does not keep pace with the vertical space created. The extent to which the tide range changes with sea level rise (if at all) depends on the modified depth and width of the estuary, which is difficult to predict given the number of variables involved. For this reason it is problematic to forecast how the salinity of estuarine waters will change with sea level rise independent of other factors such as climatic changes in freshwater runoff and human influences on the geometry of the basin.

Changes in salinity and sedimentation patterns from sea level rise could be a stressor to aquatic life, and will be most harmful for organisms that cannot easily migrate in response to changes like oyster beds. It should be noted that estuarine settings naturally experience a wide range of salinity, so organisms that inhabit these environments are generally well-adapted to this variability.

Potential Economic Impact: Drinking water reliability in Delaware is highly dependent on surface water withdrawal in New Castle County (the rest of the state utilizes groundwater for drinking water). An increase in salinity near drinking water intake pipes could affect the quality and reliability of drinking water for thousands of citizens. If augmentation of drinking water infrastructure is necessary to mitigate increased salinity, associated costs may be substantial.

Additionally, changes in salinity could cause changes in habitat for species that have commercial and recreational value. Industrial facilities dependent upon freshwater withdrawals may also be affected to varying degrees by salinity changes. Increased salt content in process water may affect some operations; require alternate sources of freshwater, or other economic hardship. Economic impacts to industrial facilities from sea level rise are covered in more detail in the Society & Economy chanter of this assessment.

Potential Social Impact: Changes to habitats for species with commercial or recreational value as a result of saltwater intrusion could result in impacts to local communities with historic and economic ties to those resources. Industries or municipalities that rely on fresh water for industrial processes or drinking water may be adversely affected by salt water intrusion, which in turn could lead to reduced production, fewer jobs, and resultant community impacts.

Potential Environmental Impact: Sea level rise could potentially increase the tidal prism volume of estuaries in Delaware, increasing the mean salinity of the estuaries, and causing salt to migrate landward into what is currently tidal fresh water. The combination of higher water levels and increased salinity could impact tidal wetlands by increasing the frequency of inundation and the salinity of tidal waters.

Increased salinity may impact plants and animals sensitive to changes in salt content. Sessile species such as shellfish are most vulnerable to these changes. Over time, shellfish beds may shift inland, but that requires time and appropriate bottom substrate in the new location. An additional concern specific to the Eastern oyster (Crassostrea virginica) is the correlation between increased salinity and disease prevalence. Oysters are primarily a mesohaline species whose population is limited at higher salinities by major predators (oyster drills and starfish). Although not harmful to humans, two parasitic diseases, MSX and Dermo, are extremely lethal to Delaware's native oyster population. These diseases thrive in warmer, higher salinity environments. Since MSX was introduced, it has become a second factor killing oysters at salinities above 15 ppt. The disease Dermo is less prevalent in the Delaware 8ay but still a concern. Increased prevalence and infection occur in waters with salinity concentrations between 12-15 parts per thousand (Virginia Institute of Marine Science, 2012).

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Changes in salinity will also affect fish species like American shad, river herring, and striped bass which live in salt water but return to freshwater rivers to spawn. These recreationally important species would be negatively affected by decreased tidal freshwater acreage that could be caused by rising sea levels and saltwater intrusion. A decrease in suitable freshwater habitat would likely result in a decrease in spawning areas and a decrease in juvenile foraging areas, leading to population declines.

Another important anadromous species is the Atlantic sturgeon, a state and federally endangered species. The spawning grounds are unknown; however, less tidal freshwater acreage reduces the potential area for spawning and early larval stage. Additionally, juvenile foraging area will be reduced and likely reduce the production capacity of the system.

Alternately, increased salt content might make the bay more suitable for other coastal species that prefer a higher salinity.

Additional Information. The Delaware Division of Fish and Wildlife have identified the Marcus Hook anchorage and Chester Island areas as potential spawning grounds at the edge of the salt to fresh transition zone based on the presence of adult male Atlantic sturgeon in May and early June. This area is currently being targeted by an ongoing Delaware State University study of sturgeon. Increased salinity could be devastating to these areas (if they are in fact used as spawning grounds or early larval staging area).

The Delaware River Basin Commission (DRBC) is the agency responsible for managing flows in the Basin. Managing releases of water from upstream dams and regulating the allocation of water is the primary tool for managing salinity levels, and the salt line is one target that the DRBC uses in its management efforts.

Extensive information on Delaware Bay oyster populations and climate change impacts can be found in Appendix O. Oysters in Delaware Bay – Climate Change of the report titled, Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning (Kreeger, et al., 2010).

#### Groundwater

Delaware's groundwater is one of its most important natural resources. It is essential for meeting the needs of all segments of our society and for maintaining economic growth and agriculture. At this time, all water used for public and domestic supply and more than 98% of water used for irrigation south of the Chesapeake and Delaware Canal is groundwater. North of the canal, approximately 70% of public water supplies are obtained from four surface-water sources (creeks) and 30% from ground-water resources (Delaware Geologic Survey).

Exposure to Sea Level Rise: Rising sea levels could increase the salinity of rivers, bays, and the groundwater tables in the state. Shallow coastal aquifers are particularly vulnerable. As rising water levels submerge low-lying sections of land, portions of the aquifer could become saline. Aquifers recharged by fresh water regions of the Delaware River may become saline in the future as well, if salt water pushes further up the waterway.

The inundation scenarios used to assess resources affected by sea level rise are ill suited to provide a meaningful assessment of potential groundwater impacts. Hydraulic interactions between sea level, aquifers, precipitation, streams, and other surface waters are too complex to draw conclusions based on just the increase in water level assumed in the three scenarios. However, a data layer available that is related to potential groundwater impacts from rising sea levels is the Undeveloped Recharge Areas layer. A groundwater recharge area is a region where water from precipitation is transmitted through the soil layers to an aquifer. Developed parcels and impervious surface prohibit effective recharge so for the purpose of this assessment, only the undeveloped recharge areas were analyzed. This data layer was generated using impervious surface data in conjunction with the recharge areas layer to identify undeveloped areas that would infiltrate precipitation. Statewide, the percentage of undeveloped recharge areas that could be inundated by sea level rise ranges from 2% to 4% (Table 3).

Table 3 - Undeveloped Recharge Areas

		Ac	Acres Inundated Percent o		of Total Inc	indated	
County	Total Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	396,107	7,788	12.682	17,358	2%	3%	4%
New Castle	16,658	31	35	40	< 1%	< 1%	< 1%
Kent	150.483	1,098	2,288	3,746	1%	2%	2%
Sussex	228,967	6,659	10,359	13,572	3%	5%	6%

Sources: DNREC, Recharge Areas, 2010-10-27, Office of State Planning Coordination, 2007 Impervious Surface Data, 2008 05 18

Table 4 - Wellhead Protection Areas

6			Acres		Percen	t of Total Inc	ndated
County	Iotal Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	29.224	270	613	987	1%	2%	3%
New Castle	12,977	43	133	175	<1%	1%	1%
Kent	6,684	104	159	228	2%	2%	3%
Sussex	9,563	123	321	585	1%	3%	6%

Source: ONREC, Statewide Wellhead Protection Areas 2009, 2009-09-29

A wellhead is the physical structure of a well above ground. Wellhead data analyzed for this assessment is for public water supply sources. Private wells and irrigation wells were not analyzed because the data is not available for public use. Areas surrounding public water supplies are designated as wellhead protection areas and regulated by DNREC to control land use activities that may prove detrimental to the groundwater resource. Statewide, 1% - 3% of the total acreage of wellhead protection areas could be inundated by sea level rise. The highest level of potential impact is in Sussex County where up to 6% of the public wellhead protection areas could be inundated by sea level rise (Table 4).

Potential Economic Impact: Saltwater intrusion to groundwater resources could affect the reliability of drinking water for hundreds of thousands of people. If augmentation of drinking water infrastructure is necessary as a result of sea level rise, associated costs may be substantial. Further, the negative economic effects of salt-contaminated groundwater can extend far beyond the costs of remediation or replacement. Many farms and neighboring communities depend on groundwater withdraws for farm operations and domestic water consumption. Salt-contaminated groundwater can discourage new businesses or residents from locating in a community. Existing businesses reliant on groundwater may be forced to move to an area with access to an uncontaminated water supply.

Potential Social Impact: Delawareans rely extensively on groundwater withdrawals for all water used for public and domestic supply. Any disruption to a society's supply of fresh, potable water has far reaching impacts. The effects would result in disruptions to daily life, public health concerns, agricultural production issues, and consequences to industrial facilities that rely on fresh water for processing. If a groundwater supply is contaminated by salt water from rising seas, there will be a pressing need to locate a clean freshwater supply, inform the public, and determine a long-term solution. Once a water supply is contaminated, replacement is often the most reasonable alternative and the costs of siting new wells, treating existing supplies, or providing bottled water are high.

Potential Environmental Impact: Impacts to aquifers similar to the potential stresses of sea level rise already occur during times of severe drought. Many shallow aquifer systems along the Atlantic coast are in direct hydraulic connection with streams and other surface waters that are often sources of recharge to the underlying ground-water system.

## The USGS summarizes the impacts of sea level rise on aquifers

Perhaps most fundamentally, a landward movement of seawater would push saltwater zones in coastal aquifers landward and upward, which could accelerate rates of saltwater intrusion into aquifers already experiencing saltwater contamination. Rising sea levels also might cause upstream migration of saltwater in coastal estuaries, inundation of low-lying areas including wetlands and marshes, and submergence of coastal aquifers. In some areas, sea level rise would erode beaches and bluffs, leading to shoreline retreat, narrowing of aquifers, and diminished areas of aquifer recharge. Sea level rise also might cause increases in coastal ground-water levels, because of the overall rise in the position of the freshwater-saltwater interface.

Although sea level rise could increase saltwater intrusion into coastal surface and groundwaters, landward saltwater movement also will depend in part on changes in precipitation, runoff, and recharge that may occur within coastal watersheds. For example, increased freshwater runoff could counterbalance the landward movement of saltwater. Moreover, should saltwater intrusion into coastal aquifers occur in response to sea-level rise, it is likely that some aquifers may require hundreds to thousands of years to re-equilibrate to changes in sea level, such as has occurred in parts of the Northern Atlantic Coastal Plain aquifer system where freshwater-saltwater interfaces appear to be still responding to sea-level increases that began at the end of the last ice age. (Barlow, 2003)

#### Wetlands

For the purpose of this assessment, wetlands are broken into the categories tidal wetlands, non-tidal wetlands, and man-made impounded wetlands. The impact tables for tidal wetlands are further broken down by impacts to saltwater tidal wetlands and impacts to freshwater tidal wetlands; however the discussion of economic, social and environmental impacts refer to all tidal wetlands. Similarly the impact tables for non-tidal wetlands are subcategorized by emergent, shrub, and forested wetlands, but the discussion of impacts addresses impacts from non-tidal wetlands combined.

#### Tidal Wetlands

Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Without these tidal wetlands, populations of migratory birds and fish would be impacted, thus shifting traditional patterns and altering ecosystems elsewhere. As a result, it can be said that while the primary users of the tidal wetlands are Delaware residents and visitors, the existence and the continued health of our tidal wetlands are important to communities throughout the United States.

Additionally, both saltwater and freshwater tidal wetlands sequester more carbon than any other habitat type in the Delaware Estuary (Kreeger, et al., 2010). Carbon sequestration is important to combating climate change—an issue of international importance.

Many different human and non-human communities use tidal wetlands and derive significant benefits from them. Human users of tidal wetlands are primarily Delaware residents and visitors. Groups of human users can be split into two categories- those who knowingly and directly benefit from being physically present the tidal wetlands, and those who indirectly and perhaps unknowingly benefit from the existence of the tidal wetlands.

Tidal wetlands act as sponges, soaking up floodwaters and buffering storm impacts. This function provides a

#### valuable service to coastal communities

Tidal wetlands also act as a sink for nutrients and pollutants to help maintain water quality. Freshwater tidal wetlands in particular are also a first line of defense for capturing contaminants flowing from urban lands to the estuary. The nutrient storage and sequestration function of saltmarshes is of particular importance to Delaware's Inland Bays and tributaries to the Delaware Bay which suffer from excess nutrient pollution. Tidal wetlands remove excess nitrogen entering the estuaries from both non-point sources and direct deposition from the atmosphere.

#### Saltwater Tidal Wetlands

Saltwater tidal wetlands are low flat marshlands inundated by salt water. These tidal wetlands form a continuous fringe around the Delaware Bay and Inland Bays. While it is possible that some saltwater wetlands will migrate landward and upward in response to sea level rise, due to the limitations of the bathlub model used for this assessment, the exposure values discussed below do not take into consideration natural processes of erosion, accretion and landward migration

Exposure to Sea Level Rise: Saltwater tidal wetlands are extremely vulnerable to sea level rise, as indicated by the figures in the Table 5 (and depicted on maps in the Mapping Appendix). However, the extent to which a given tidal wetland is vulnerable to sea level rise depends on several factors: the burial rate of organic and inorganic sedimentary matter; the rate of regional land subsidence relative to the rate of sea level rise; and the degree to which coastal development, topography, and other factors limit the landward migration of marshes. Tidal wetlands grow vertically through accretion. They do this by capturing sediment brought in by the tides and by maintaining high plant production above ground and slow decomposition rates below ground. By accumulating dead plant matter and inorganic sediment, established marshes generally accrete at rate sufficient to keep pace with sea level rise. However, accelerating rates of sea level rise are likely to alter wetland accretion dynamics in some areas and the potential impact on accretion rates depends on interplay

between the biotic and physical factors involved. The rate of sea level rise is critical, and we can expect many of our tidal wetlands to drown under the higher sea level rise scenarios (Kirwan, Guntenspergen et al. 2010).

Table 5 - Tidal Wetlands

County	Total Acres		Total Acres Inundated			ercent of Tot res Inundat	
	of Wetlands	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	73.408	71,172	72,956	73,141	97%	99%	99%
New Castle	16,113	14,614	15,755	15,877	91%	98%	99%
Kent	36,205	35,609	36,152	36,191	98%	99%	99%
Sussex	21,090	20,949	21,048	21,073	99%	99%	99%

Source: DNREC, Delaware Wellands SWMP 20100901, unpublished

Tidal wetland acreage during periods of rising sea level is also determined by the capacity of marshes to migrate landward and upward (transgress) over adjacent uplands. The rate of marsh migration under a given rate of sea level rise is determined primarily by the slope of adjacent lands and their management. Rates of marsh migration are lower where the slopes of adjacent lands are higher (Carey, 1996). Migration can be stalled by naturally steep slopes or land management activities that raise the elevation of adjacent lands or harden the upland wetland boundary. This will stall the migration of wetlands until sea levels rise enough to push marshes past the obstructions. Where obstructions include (or are protecting) infrastructure like roads, communities will likely be inclined to prevent this process for as long as possible. Under conditions of rapidly rising sea levels, landward wetland migration is likely to be the primary process by which wetlands maintain their acreage and function, if such migration is possible (CCSP, 2009).

A recent report, Delaware Wetlands: Status and Changes from 1992-2007, identified a loss of 579.5 acres of tidal wetlands, attributing 83% of the loss to conversion to open water. However, a portion of this acreage lost was offset by gains elsewhere resulting in a net loss of 238 acres (Tiner, Biddle, Jacobs, Rogerson, & McGuckin, 2011). These trends are expected to continue and likely increase with climate change impacts, including sea level rise. Sea level rise will interact with various other stressors to push many wetlands past their sustainable threshold (Kreeger, et al., 2010).

#### Freshwater Tidal Wetlands

Freshwater tidal wetlands occur at the upper reaches of estuaries where the water level is influenced by the rise and fall of the ocean tides, but is beyond the salt line. Freshwater tidal wetlands were not mapped separately but the acres inundated were included within the broader category of tidal wetlands (Maps 1-3 in the Mapping Appendix). However, because freshwater tidal wetlands are ecologically important and known for high species diversity, they are addressed separately here. The tables below represent freshwater tidal wetlands combined (Table 6) as well as separated into two types: mixed broadleaf (Table 7) and forested and shrub (Table 8). This data was provided by the Delaware Natural Heritage Program and was obtained through both field verification and interpretation of aerial and satellite photographs.

Exposure to Sea Level Rise: Freshwater tidal wetlands are very vulnerable to sea level rise, as indicated by the results of the exposure assessment in Tables 6-8. The extent to which a given freshwater tidal wetland is vulnerable to sea level rise depends on the factors noted above for salt marshes. Additionally, the degree to which sea level rise increases the salinity of tide water is another factor, because salinity limits the types of flora that colonize the marshes.

Table 6 - Freshwater Tidal Wetlands

. Total Acres			Total Acres	Total Acres Total Acres Inundated			Percent of	Total Acres	Inundated
County	of Tidal Marsh	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m		
State	11.052	9,264	10,638	10.828	84%	96%	98%		
New Castle	3,368	2,351	3.202	3.306	70%	95%	98%		
Kent	1,749	1,286	1.881	1,714	74%	96%	98%		
Sussex	5,934	5,628	5,755	5,806	95%	97%	98%		

Source: DNREC - Natural Heritage Program Habitats of Conservation Concern (2011), unpublished

Table 7 - Mixed Broadleaf Freshwater Tidal Marsh

	Total Acres	Total Acres Inundated			Percent of	Total Acres	tal Acres Inundated	
County	of Tidal Marsh	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	5,933	4,683	5,797	5,887	79%	98%	99%	
New Castle	3,143	2,195	3,011	3,099	70%	96%	99%	
Kent	298	1	298	298	< 1%	99%	99%	
Sussex	2,491	2,487	2,489	2,489	99%	99%	99%	

Source: DNREG - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Freshwater tidal wetlands are expected to grow vertically to keep pace with accelerating rates of sea level rise in most areas, but only if they are not exposed to salt water.

Due to possible increases in salinity associated with sea level rise (and possibly other system alterations) at least some transitional brackish and freshwater tidal wetlands are expected to be exposed to increasing salinity. As salinity increases in freshwater tidal wetlands, freshwater-adapted species die, and salf-tolerant species may or may not replace them. Some new research is finding that sometimes there is insufficient time for belowground processes to shift and the soils become toxic to most vegetation due to redox changes (Carey, 1996).

Table 8 - Freshwater Tidal Forested and Shrub Wetlands

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
	of Wetlands	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	5,119	4,581	4,841	4.941	89%	95%	97%
New Castle	225	156	191	207	69%	85%	92%
Kent	1,451	1,285	1,383	1,416	89%	95%	98%
Sussex	3,443	3,141	3,266	3,317	91%	. 95%	96%

Source: DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Freshwater wetland acreage during periods of rising sea level is also determined by the capacity of these wetlands to migrate over adjacent uplands. In more landward areas upriver, it may be possible for some freshwater tidal marshes to 'out run' sea level rise by migrating inland, but this depends on the rate of change and the capacity to move into inland areas. Rates of migration are lower where the slopes are adjacent lands are higher, and migration can be stalled by natural steep slopes or land management activities that raise the elevation of adjacent lands or harden the upland wetland boundary. This will stall the migration of wetlands until sea levels rise enough to push wetlands past the obstructions. According to several studies, landward migration of freshwater tidal marshes in Delaware is very unlikely since many of these coastal areas are developed or 'hardened.' (Kinwan & Guntenspergen, 2010) Where obstructions to migration include or protect important infrastructure like roads and structures, taking action to allow migration is complicated and may be unlikely.

Because of the relative rarity of these wetlands in Delaware and their high natural capital value (described below), preventing inundation or change due to sea level rise is especially important.

Potential Economic Impact: While no specific economic data is available for economic production from tidal wetlands in Delaware, an assessment of the economic value of the state of New Jersey's natural resources determined that tidal wetlands provided \$6,269 per acre per year in total goods and services to residents and visitors (State of New Jersey, 2007). These estimates can be reasonably applied to tidal wetlands in Delaware.

Loss of associated ecosystem services: Associated ecosystem services include water filtration, carbon sequestration, flood protection, and habitat critical to fisheries and shellifisheries. According to an assessment by the Water Resources Agency of the University of Delaware in 2011, saltwater tidal wetlands provide an average of \$7,235 per acre in ecosystem services (Kauffman, Homsey, Chatterson, McVey, & Mack, 2011). Losing 97% of Delaware's saltwater tidal wetlands, the most conservative number, would result in the loss of over \$500 million of ecosystem services per year. The same study valued freshwater tidal wetlands at an average of \$13,621 per acre in ecosystem services. Losing 79% of Delaware's mixed broadleaf freshwater tidal marsh, and 89% of Delaware's froshwater tidal forested and shrub wetlands (the most conservative estimate) would result in the loss of over \$125 million of ecosystem services per year. This analysis does not account for many secondary economic or climate impacts. For example, the loss of more than 70,000 acres of tidal wetlands would result in a large pulse of carbon dioxide due to respiration of outwelled peat, thereby contributing a positive feedback for greenhouse gas emission.

Loss of tourism/recreation: According to the same study, the estimated economic value associated with fishing, hunting, and wildlife watching along coastal Delaware is \$134 million annually. This value is derived from estimates of trip related expenditures including food and lodging, transportation, and hunting, fishing, and wildlife watching equipment (Kaufman, Homsey, Chatterson, McVey, & Mack, 2011). Given the important role of tidal wetlands in fish production and natural habitats in coastal Delaware and the unique habitat niche filled by freshwater tidal wetlands, it is likely that a large portion of this value can be attributed at least in part to tidal wetlands.

Loss of jobs: While there are no specific estimates regarding what would happen to commercial fishing operations if 97% of Delaware's saltwater tidal wetlands, 79% of Delaware's mixed broadleaf freshwater tidal wetlands and 89% of Delaware's freshwater tidal forested and shrub wetlands were inundated, it is likely that this industry would suffer some type of decline. It is estimated that anywhere from 85%-95% of our recreationally and commercially important coastal fisheries rely on tidal wetlands as a place to shelter and grow their young (Department of Natural Resources and Environmental Control, 2011).

Loss of flood protection. Though it was mentioned above during the discussion of ecosystem services, the importance of flood protection to coastal communities cannot be overstated. Without wetlands to attenuate flooding effects from storms, damage to homes, businesses and infrastructure would likely increase significantly. Coastal tidal wetlands are especially important for absorbing or dissipating atorm surge effects.

Potential Social Impact: Losing significant acreage of tidal wetlands would result in quality of life impacts, including the loss of income for commercial fishers; loss of hunting and fishing opportunities; and increased flooding for coastal communities. These losses, combined with increased flooding, could affect the social fabric and sustainability of Delaware's coastal communities.

Potential Environmental Impact: The inundation of saltwater tidal wetlands could create major environmental changes including:

- · Shifts in community species composition (including loss of rare plants)
- · Changes to extent of wetland areas
- Changes to the ratio of shoreline edge to marsh area
- Changes to the rate of channel scour
- · Increase in storm surge susceptibility · Reduction in fisheries production
- · Reduction in water quality

The impact of sea level rise and resulting salinity changes on freshwater tidal wetlands could create major changes to these areas. In a recent estuary-wide study, wellands experts expressed a high concern about the following changes to freshwater tidal wetlands as a result of sea level rise and resulting salinity changes:

- · Shifts in community species composition
- Saltwater intrusion to freshwater habitats
   Changes in habitat support
- Ability for wetlands to migrate landward
- · Change to extent of wetland areas
- · Increase in storm surge susceptibility
- · Increased seaward edge erosion
- · Increased salt exposure/stress/event

(Kreeger, et al., 2010)

As sea levels rise and wetlands migrate inland where they are able, there will be shifts in species composition and habitat types. Within salt marshes, low-marsh species will replace mid- and high-marsh species. Similarly, salt marshes will replace brackish marshes.

Sea level rise over time changes the salinity of freshwater tidal wetlands in Delaware. Salinity changes will replace freshwater tidal wetlands with brackish wetlands or open water, which will cause major shifts in species composition. In addition to their vulnerability to salinity, freshwater tidal wetlands are threatened by the physical effects of rising sea level, such as erosion of seaward edges. Some freshwater tidal wetlands may convert to brackish wetlands, possibly dominated by invasive species that thrive under more frequent disturbance regimes (Kreeger, et al., 2010).

#### Non-tidal Freshwater Wetlands

Non-tidal freshwater wetlands (also known as palustrine wetlands) in Delaware are mostly held in private ownership with the majority of the total acreage located in Kent County and Sussex County. GIS mapping indicates that there are approximately 163,000 total acres of non-tidal freshwater wetland in Delaware, of which 86% is forested. These wetlands exist as floodplains of natural stream channels, as ditched modifications and extensions of natural streams, and as isolated systems. Non-tidal freshwater wetlands represent a large proportion of the forested area in Delaware and are too wet to build upon or farm without substantial draining or filling.

Historically, non-tidal freshwater wetlands have been used for lumber production. Until the passage of laws pertaining to the handling of rubbish and other garbage in the mid-twentieth century, these wetlands were frequently used as "dumps." With the exception of some hunting and naturalist activity, usage by people is light. Habitat quality and species diversity varies and all three subcategories discussed here are used by a variety of wildlife.

Exposure to Sea Level Rise. The tables below summarize the results of the sea level rise exposure assessment for non-tidal freshwater wetlands. Results are divided into three categories: non-tidal emergent wetlands (Table 9), non-tidal forested wetlands (Table 10), and non-tidal shrub wetlands (Table 11), Inundated acreage determinations are based on data generated by the DNREC. All computer-generated numbers are rounded to two significant figures to avoid the presentation of numbers that are unrealistically precise thus slight disagreements exist between the state total and the sum of the county totals. Corresponding maps are located in the Mapping Appendix.

Table 9 - Non-Tidal Emergent Wetlands

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated			
	of Emergent Wetlands	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	8.873	2.236	2,950	3,140	25%	33%	35%	
New Castle	2,602	635	761	818	24%	29%	31%	
Kent	2.178	253	695	742	12%	32%	34%	
Sussex	4,093	1,348	1.494	1,580	33%	37%	39%	

Source: DNREC, De\_Wellands\_20100901\_PD6, 2010-09-01

Potential Economic Impact: A loss of non-tidal freshwater wetlands may result in increases in flooding and/or increased expenditure of funds for stormwater projects to prevent flooding. As the acreage of these wetlands declines, the delivery of nutrients and suspended sediments to downstream waters is expected to increase. This could lead to detrimental economic and environmental outcomes including decreased water quality, increased cost of pollutant removal and disruptions to fish and waterfowl populations.

Table 10 - Non-Tidal Forested Wetlands

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
	of Forested Wetlands	0.5 m	1.0 m	1.5 m	<b>0.5 m</b> 6% 5%	1.0 m	1.5 m
State	140,891	8,192	10.828	12.605	6%	8%	9%
New Castle	12,614	607	851	998	5%	7%	8%
Kent	53,878	2,403	3.623	4.383	4%	7%	8%
Sussex	74,399	5,181	6,354	7,224	7%	9%	10%

Source: DNREC. De\_Wellands\_20100901\_PD6, 2010-09-01

Potential Social Impact: The flood controlling function of these non-tidal freshwater wetlands has societal value. Intrinsic value such as catchment basin-like topography, flow-impeding roughness of the ground surface and the seasonal transpiration of the trees, shrubs, and herbaceous plants allow stormwater to be retained, with some being recharged to groundwater and the remainder being discharged relatively slowly downstream or to the almosphere by evapotranspiration. These functions result in water quality and water quantity benefits.

Table 11 - Non-Tidal Shrub Wetlands

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
	of Shrub Wetlands	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	13,178	2,446	2,886	3.104	19%	22%	24%
New Castle	973	325	429	463	33%	44%	48%
Kent	2,624	868	1.090	1.167	33%	42%	44%
Sussex	9,581	1,253	1,367	1,474	13%	14%	15%

Source. DNREC, De\_Wetlands\_20100901\_PD6, 2010-09-01

Flooding, whatever its cause, results in social impacts as well as economic loss. With regard to the loss of nontidal freshwater wetlands to sea level rise, social impacts are closely intertwined with environmental impact. The loss of wetlands and associated changes in ecological character of an area may occur so slowly as to be indiscernible to anyone other than a trained ecologist. History suggests that gradual and subtle losses are unlikely to elicit much concern on the part of the general public.

Finally, these highly complex ecosystems serve as important wildlife habitat to a wide variety of species. In addition, waterfowl hunting, bird watching, and nature photography are popular activities in and around non-tidal wetlands. Therefore loss of recreational opportunities could also be considered a social impact.

Potential Environmental impact: As water moves downstream, wetlands improve its quality by functioning as a purifying filter. Nutrients are used by the vegetation while suspended sediments settle, elevating the floodplain and thereby somewhat offsetting the coinciding sea level rise. Such retention of nutrients and sediments by wetlands of any kind reduces the quantities delivered downstream. Fisheries and migratory waterfowl populations have been disrupted by environmental conditions resulting from these pollutants including low dissolved oxygen, loss of seagrass, and blooms of undesirable algae.

The retention capacity of wetlands serves to reduce the quantity of stormwater flow carried by a stream bed. This can reduce the failure of stream banks, which leads to detrimental outcomes including the loss of riparian trees that shade the water, the elimination of pools as fish habitat due to filling with silt, sand and gravel, and the widening and shallowing of the stream channel such that summer water temperature becomes too high to support many plants and animals.

The shrinking of habitat will result in a decrease in environmental carrying capacity, cascading to a reduction in abundance at the species level and diversity at the community level. Many such impacts may be "silent" and go unnoticed by the general public.

Additional impacts are listed below:

- · Alteration of species diversity (locally)
- · Alteration of species diversity (landscape)
- · Alteration of species composition
- Alteration of habitat structure
- · Conversion of one habitat type to another
- Conversion to tidal wetlands
- . Conversion to open water
- Salinization of aquifers
- Alteration of flood water retention
- Alteration of nutrient dynamics
- · Alteration of sediment transport
- · Alteration of land subsidence rate
- · Alteration of wetland accretion rate
- · Increased stress on forested communities result disease outbreaks
- Alteration of invasive community dynamics
- · Introduction of and susceptibility to pathogens and parasites
- · Alteration of woodlands to emergent shrub, forb, or grass species
- Shift to more salt tolerant species
   Altered susceptibility to wildfire
- · Local extirpation of rare/endangered flora and fauna
- Increased human pressure on remaining land base

(Tiner R. W., 1985)

Additional Information: Many non-tidal freshwater wetlands are not regulated and can be filled or altered without permits. Because of this, losses due to sea level rise will likely be obscured by losses due to other types of human activity such as agriculture and development.

It should be noted that the exposure assessment estimates do not take into account the generation of new palustrine wetlands that can be expected to develop in some places as the water rises and the uplands retreat.

An in-depth evaluation of current landscape use and ownership within and around vulnerable wetlands may provide useful information to guide adaptation recommendations. This information coupled with current land use and zoning regulations and various sea level rise scenarios could be used to make predictions about future losses and gains in acreage and functions.

#### Impoundments

Coastal impoundments are man-made structures that primarily serve to provide important breeding, migration, and wintering habitat for a variety of birds. They also serve as nurseries for fish and help control mosquito populations. In addition, they provide important recreational opportunities such as bird-watching and fishing. Alongside these uses, impoundments also provide flood control for many coastal communities, roadways, and agriculture resources. The coastal impoundments have a variety of owners and management objectives which causes landscape-scale management to be a complex problem, especially in the face of sea level rise. The largest owners of impounded wetlands are the U.S. Fish & Wildlife Service, the DNREC Division of Fish and Wildlife and the city of New Castle. The U.S. Fish & Wildlife Service owns and maintains impoundments at Bombay Hook and Prime Hook National Wildlife Refuges that were created to provide habitat for waterfowl. The DNREC Division of Fish & Wildlife owns and operates several impoundments throughout the state that were created to provide habitat for waterfowl, migratory shorebirds, and to control mosquito populations. The City of New Castle owns and maintains several impoundments that were created to provide flood and storm water control for the city.

Wetland loss, whether the wetlands are natural or managed, will have dramatic consequences for wildlife populations. Therefore, management of impounded wetlands needs to be conducted in the short term to maximize the services they perform annually but also must be conducted in the long term to ensure they will be available for, and provide utility to, sea level rise adaptation. An impoundment management plan that addresses the interconnectedness of impoundments and their surrounding habitats in an adaptive way and within the context of sea level rise will help to ensure wetland habitat is available over the long term.

Exposure to Sea Level Rise: Breaching of freshwater or brackish impoundments threaten the flora and fauna within these habitats. Increasing the duration of tidal flow and salinity concentration raises the potential of permanent inundation and vegetation dieback, which could result in impoundments converting into a permanent open water body. A sea level rise of 0.5 meters could result in inundation of 81% of the state's impoundments. At 1.0 and 1.5 meters of sea level rise, 99% of all impoundments could be affected (Table 12 and maps in the Mapping Appendix).

Table 12 - Impoundments

County	Total	Total	Acres Inune	lated	Percent of Total Acres Inundate		
	Impoundment Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	12,236	9,961	12,107	12,176	81%	99%	99%
New Castle	2,832	2,007	2,870	2,876	70%	99%	99%
Kent	2,950	1,800	2.935	2,946	61%	99%	99%
Sussex	6,403	6,154	6.302	6,354	96%	98%	99%

Source: Delaware Coastal Programs, Impoundments (2010), unpublished.

Potential Economic Impact: The economic impact is unclear. Potential losses may come indirectly as a result of reduced ecotourism and associated dollars spent on lodging, food and equipment. No economic data specific to impoundments has been generated.

Potential Social Impact: Coastal impoundments provide important breeding, migration, and wintering habitat for a variety of birds. They serve as nurseries for fish and help to control mosquilo populations. In addition, they provide important recreational opportunities. Loss of impoundments could result in loss of historic and cultural connections to such activities as waterfowl hunting, trapping, and bird watching.

Potential Environmental Impact: These freshwater, brackish, and tidal impoundments fill a void in the distribution of wetlands along the coast, as human activities have resulted in a loss of freshwater and brackish wetlands. The habitat that is provided by the impoundments has become a core component of the distribution of available habitat in the Mid-Atlantic for migratory waterfowl, shorebirds, wading, and ground birds. The loss of these areas could result in a large scale shift in the distribution of birds within Delaware and the Delmarva Peninsula.

Additional Information; Detailed information on types of habitat loss may be available from data collected from each affected impoundment.

#### Beaches and Dunes

The coastline of Delaware is a vital economic and environmental resource. Its 24 miles of Atlantic Ocean shoreline and 357 miles of river and bay shoreline provide economic benefits from tourism, high-value space for commercial and residential development, and recreational opportunities including boating, fishing, and beach-going. Delaware's shoreline is also an important ecological resource—providing habitat for a variety of plants, animals, insects, and migratory birds.

The assessment below focuses on the ecological impacts of sea level rise to beaches and dunes. Impacts to beaches and coastal communities resulting from these impacts are also addressed within the Tourism section of the Society and Economy chapter of this document.

Operating in tandem with the Sea Level Rise Advisory Committee is another state committee focused on the communities of Delaware's Bay Beaches. The Delaware Bay Beach Work Group (also known as the Simpson Bushweller Committee) has provided the Governor with 14 short-term recommendations to help alleviate (looding and erosion problems in these areas. The Delaware Bay Beach Work Group will also provide recommendations for addressing the long term issues threatening these coastal communities including storms, rising sea levels, subsidence, beach erosion, and flooding. These recommendations will assist the State in developing a sustainable long-term strategy, including new approaches to financing restoration work (Delaware Bay Beach Work Group, 2011). This document will refer readers to their work considering these at-risk coastal communities.

Exposure to Sea Level Rise. Typically, Delaware's beaches include a berm and dune system. The berm and dune system naturally transgress or migrates landward, but infrastructure built on areas along the coast block that process, instead, material is eroded and carried offshore. This decreases beach width and berm height, thus eliminating or damaging the dune systems, exposing coastal properties to storm damage.

Sea level rise has the potential to exacerbate the damaging effects of coastal storms by increasing the severity of flooding in coastal communities. When combined with wind-driven waves, sea level rise can cause shoreline erosion that leaves roads, boardwalks, hotels, and houses along the coastline vulnerable to storm damage.

There is no data table presented here to quantify acreage impacts to beaches. Because beaches erode and accrete naturally on a short term basis and public beaches are augmented with periodic sand replenishment projects, it may not be apparent that sea level rise is affecting beaches. Often the impacts are more obvious on the bay/wetland side of barrier beaches because without replenishment projects, as the water rises, more land is lost. The degree to which a beach would be affected by sea level rise is difficult to ascertain given the dynamic nature of the habitat. Dramatic changes can be seen annually between winter and summer beach profiles and the natural landward migration of the beach and dune habitat. Periodic beach re-nourishment efforts in developed coastal areas continually reshape the coastline.

Inter-dunal wetlands are a unique coastal dune habitat type at risk from sea level rise. These small wetlands are found only among maritime dunes along the Atlantic Coast. Despite their proximity to the ocean, their seasonal flooding is driven by groundwater and precipitation. As dynamic as many other beach and dune habitats, these swales are periodically created or destroyed by major storms. Some types are wholly herbaceous vegetation, while others are dominated by shrubs. More than 20 types of rare plants are found in these wetlands. There are 72 acres of this habitat type in Sussex County, Delaware, mostly on protected state parkland. A small percentage would be affected at the 0.5 m scenario but the 1.0 m and 1.5 m scenarios indicate a more drastic impact of 81% and 94% respectively (Table 13). Impacts from predicted sea level rise, made worse by disturbance of normal coastal processes, could be substantial. Note that although inter-dunal wetlands are part of a very dynamic coastal ecosystem, their recovery from disturbance – including sea level rise – is believed to be fairly slow because a thin layer of peat must develop on the sand to establish the plant community. Note: the economic, social, and environmental impacts discussion below refers to the broader category of Beaches and Dunes, not just inter-dunal wetlands.

Table 13 - Inter-dunal Wetlands

County	35 A. T. Const.	Total Acres Inundated			Percent of Total Acres Inundated		
	Iotal Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	72	3	58	68	5%	81%	94%
New Castie	0	0	0	0	0%	0%	0%
Kent	0	0	0	0	0%	0%	0%
Sussex	72	3	58	68	5%	81%	94%

Source: DNREC-Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Potential Economic Impact: Based on 2008 statistics from the Delaware Tourism office, the tourism industry was the 5th largest employment sector in the state accounting for 8.3% of Delaware's total employment. The industry brought in approximately \$408 million in state and local taxes and fees that year. It was estimated that 16% of total trips involved beach recreation (DEDO, 2008). Delaware's bay beaches and Allantic coast beaches also provide ecotourism opportunities. A 2006 National Survey found that 395,000 Delaware residents and nonresidents fished, hunted, or watched wildlife in the state. Of the total number of participants, 159,000 fished, 30,000 hunted, and 285,000 participated in wildlife-watching activities, which included observing, feeding, and photographing wildlife (US DOI-FWS and US DOC-Census Bureau, 2006).

The most recent beach replenishment effort in 2011-2012 along the Atlantic coast beaches (Rehoboth, Dewey, Bethany, South Bethany and Fenwick) cost approximately \$38 million. This particular sand nourishment project was paid for with federal disaster relief funding. However, the initial project was funded under the typical 35% local and 65% Federal cost share.

Along the Delaware Bay coast during the same time period, beach nourishment occurred using a truck hauling method. The bay beaches replenished were Kitts Hummock with 7,000 cubic yards of sand coasting \$111,230, Bowers Beach with 13,000 cubic yards of sand costing \$206,570 and South Bowers Beach with 2,000 cubic yards of sand costing \$31,780. Unlike the Atlantic Ocean projects, these projects were funded exclusively with state funds.

Potential Social Impact: Coastal communities are intertwined with rising sea levels. The social fabric of these coastal towns is based around fishery activities, marina activities, and tourism. As long as these critical social factors are not affected by sea level rise, then these communities will be able to survive. However, the potential loss of beach access, and the loss of beach resort infrastructure may have impacts on their social structure. Further, as sea levels continue to rise, residents in some coastal communities may experience property damage, interrupted services, and access issues which will negatively affect their quality of life.

Potential Environmental Impact: Coastal habitats are adapted to the dynamic conditions of shifting sands, strong winds, and salt spray unique to the narrow zone along the Atlantic Ocean and Delaware Bay. They range from the beach – covered and exposed by the twice-daily tides – to the first grassy dunes and overwashes, to a complex of shrub-dominated back dunes.

These habitats have declined significantly in extent and quality during historical times primarily because of residential development and associated infrastructure, particularly artificial shoreline hardening, jettles, and groins. In recent decades, this decline has greatly slowed on the Atlantic Coast, where most remaining habitats are on public land. Losses continue along the shorelines of the Delaware Bay and Inland Bays. All of these habitats are subjected to on-going impacts from recreational activities, and Delaware Bay beaches in particular are occasionally impacted by oil spills. The long term prospect for beaches and dunes is potentially poor given predicted sea level rise, even though these disturbance-dependent habitats might be expected to accommodate sea level rise reasonably well by migrating inland. However, onshore and offshore coastal processes that would facilitate such a shift, especially sand transport, may have already been irreversibly compromised by the issues noted above.

Efforts to stabilize dunes may also further disrupt these processes in the future, despite their seeming benefits at present. Beach replenishment is a potential solution to the loss of natural sand transport, but costs are very high and nearshore habitats that serve as a sand source may be adversely impacted (DNREC-Div. of Fish and Wildlife. 2006).

### Upland Forest

Forests offer a wide variety of outdoor recreational activities such as hiking, jogging, biking, horseback riding, camping and hunting. They provide wildlife habitat for a variety of species and provide air quality benefits. They also provide direct economic benefits to the state through timber production.

Approximately one-third of Delaware is forested, according to the 2010 Delaware Forest Resource Assessment generated by the Delaware Forest Service. Of this, 97% is classified as potential commercial timberland and could provide benefits to the timber industry (foresters, loggers, and mills-saw timber, pulpwood, veneer, and pillings). Forests are also valuable for wildlife habitat, recreation, soil protection, water quality and quantity as well as aesthetics (Delaware Forest Service, 2010).

Exposure to Sea Level Rise: Three upland forest types were analyzed for exposure to sea level rise under the three scenarios: evergreen forest, deciduous forest, and mixed forest. However, the map (see Maps 13-15) and the discussion of impacts refers to the impact of all upland forest types combined.

The level of exposure to upland forest resources is fairly limited. The combined exposure to the three forest types represented here range from 2% to 6% of the total upland forested acreage in the state under the range of inundation scenarios (see Table 14 - 17).

Table 14 - Total Upland Forest

	Total	Total	Acres Inun	lated	Percent of Total Acres Inundated		
County	Forested Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	177,590	4,236	7,890	11.090	2%	4%	6%
New Castle	41,305	833	1.371	1,857	2%	3%	4%
Kent	35,366	1,060	2,321	3.404	3%	7%	10%
Sussex	100,919	2,344	4,197	5,830	2%	4%	6%

Potential Economic Impact: Forests provide a wide range of social and economic benefits from timber products to recreation to aesthetics. The markets for timber products are a significant sector of our state's economy. While there is no current, statistically-valid data on the contribution of the forest products industry to Delaware, it is certainty a significant component. In 2002, more than 2,600 people were employed in the forest products manufacturing industry in Delaware. Most of these jobs were located in secondary wood processing industries. Sixty-three establishments in Delaware produce a variety of products including furniture, custom millwork, cabinets, and other wood products. Approximately 4,800 acres are harvested annually–2,400 acres by clear-cut, 1,500 acres by selection harvests, and 900 acres of pine thinning (pulpwood). The Delaware Forest Service estimates that these harvests generate at least \$4 million of income for landowners annually. Furthermore, urban forests also contribute jobs to Delaware's economy. The number of tree-care companies is growing as Delaware continues to urbanize. There are now 81 certified arborists in Delaware. Nursery farms generate an estimated \$47 million in sales annually (Delaware Forest Service, 2010).

Maintaining and growing these markets is vital not only to Delaware's economy but also to sustain the forest land base; owners need to generate sufficient income from their forests to retain their forests. Furthermore, it is important to develop new markets, such as wood energy, to maintain a robust and diverse forest products economy so it is not overly dependent on a single market. Public investment in forests, forest markets, and forest research is also necessary to ensure a sustainable land base and the best information is available to landowners and decision-makers. Addressing all of these issues is necessary to help ensure that Delaware's forests will continue to meet society's needs in the future.

Table 15 - Deciduous Forest

	Total	Total	Acres Inund	ated	Percent of Total Acres Inundated			
County	Deciduous Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	58,625	1,250	2,427	3,383	2%	4%	6%	
New Castle	38,219	744	1,205	1,641	2%	3%	4%	
Kent	16,000	445	1.098	1,549	3%	7%	10%	
Sussex	4,406	61	123	194	1%	3%	4%	

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Table 16 - Evergreen Forest

	Total	Total	Acres Inund	lated	Percent of Total Acres Inundated			
County	Evergreen Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	29,190	612	1,290	1,833	2%	4%	6%	
New Castle	656	5	9	14	1%	1%	2%	
Kent	2,366	145	326	485	6%	14%	21%	
Sussex	26,168	463	955	1,334	2%	4%	5%	

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Table 17 - Mixed Forest

	Total Mixed	Total	Acres Inund	lated	Percent of Total Acres Inundated		
County	Forest Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	89,775	2,374	4,173	5,874	3%	5%	7%
New Castle	2,430	84	157	202	3%	6%	8%
Kent	17,000	470	897	1,370	3%	5%	8%
Sussex	70,345	1,820	3,119	4,302	3%	4%	6%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Potential Social Impact: Forests offer a wide array of outdoor recreation activities. Losses from sea level rise could reduce opportunities for hiking, jogging, biking, horseback riding, camping, hunting, and wildlife observation whether on private or publicly owned lands.

Potential Environmental Impact: Delaware has a large variety of forest communities in a relatively small geographic area. Delaware's bottomland forest species (oak, gum, cypress) may be particularly impacted by sea level rise. However, some of the rarer forests such as the Inland Dune Ridge Forest found in the Nanticoke River area, the Southern New England Red Maple Seepage Swamp found in the Piedmont, and the North Atlantic Coastal Oak-Holly Forest found in the Nanticoke and Choptank River watersheds could potentially be impacted. The loss of these unique forest communities will negatively impact biodiversity, buffering capacity, and wildlife habitat including migratory bird species.

While there is considerable research needed, several potential issues relating to forests and habitat include:

- Migration of maritime forests/riparian areas inland
- Shifts in species range (migration)
- Changes in species composition and/or disappearance of species
- · Increases in invasive/nuisance species and disease
- · Loss of rare plant species

Additionally, there is need to establish baseline risk assessment for species and habitats and to consider methods to move low-lying riparian forest buffers inland with any rise in sea level to ensure that these buffers are not lost. It is important that these baseline risk assessments account for possible changes from sea level rise in the future

#### Flora and Fauna

#### Habitats of Conservation Concern

The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identifies 27 unique Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure.

Exposure to Sea Level Rise: Fifteen of the 27 Habitats of Conservation Concern (HCC) identified in the Delaware Wildlife Action Plan will be exposed to sea level rise. Under the 1.5 m scenario for sea level rise, approximately half of all HCC's will be inundated and potentially lost (Table 18 and maps in the mapping appendix). The analysis indicates that habitats in Kent and New Castle Counties have a higher level or exposure than those in Sussex County.

Of those HCC's that are exposed to sea level rise, seven types (each a unique type of wetland) could experience inundation of more than 90%. However, it is unknown if, how, and where HCC's and other wetland habitats might migrate to as water levels rise.

Table 18 - Habitats of Conservation Concern (HCC)

County	Total	Total	Acres Inune	fated	Percent of Total Acres Inundated			
County	HCC Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	31,340	17,088	19,470	20,342	55%	62%	65%	
New Castle	3,945	2,480	3,334	3,441	63%	85%	87%	
Kent	7,039	5,911	6,460	6,555	84%	92%	93%	
Sussex	20,357	8,698	9,676	10,346	43%	48%	51%	

Source: DNREC - Natural Heritage Program, Habitats of conservation Concern (2011), unpublished

Potential Economic Impact: The impact of sea level rise on HCC's and their associated wetlands is enormous. Delaware, being a coastal state, relies heavily on its coastal wetlands for part of its economy. There are many ways that coastal wetlands benefit the state. For example, coastal wetlands are extremely important for providing flood protection to houses, roads and other infrastructure from storm surges resulting from hurricanes and nor/easters. They efficiently sequester nutrients and trap sediments to improve water quality. Finally, they provide spawning and nursery habitat for many of our economically important commercial fisheries including the blue crab.

Potential Social impact: The high intrinsic value of coastal wellands and their predicted loss from sea level rise will undoubtedly have impacts on society. A substantial loss of habitats of conservation concern is an indicator of overall coastal welland loss. We have become accustomed, even complacent, about the benefits of our coastal wellands and the protections to infrastructure, health and the economy they provide. Once those protections are removed, the citizens of Delaware may have to think differently about a variety of issues from how they will get around in the state to where they will find clean water.

Potential Environmental Impact: Intrusion of saltwater into freshwater is an important environmental impact of losing coastal HCC's and their associated wetlands from sea level rise. As waters push further inland, hydraulic pressure at the land/water interface will increase. That pressure will cause saline surface water to move inland underground, salinizing shallow freshwater aquifers. This interaction between saline surface water and fresh and saline groundwater would potentially lead to saltwater contamination of freshwater resources. This interaction is an area that needs further investigation to fully quantify the threats posed to freshwater resources. Other sections (salinity changes, groundwater, freshwater tidal wetlands, and non-tidal freshwater wetlands) within this assessment also identify saltwater intrusion as a pertinent issue.

Additional Information: The amount of each habitat type needs to be monitored with aerial imagery set. These maps can then be updated with each aerial imagery set in order to see whether they are decreasing or increasing. More research needs to be conducted on the resource use of the animals and whether there is a trend of their populations following the trends of the habitat or whether they are adapting to other habitats.

### Native Vegetation

Native vegetation discussed within this section includes rare, uncommon, and common species that occur in upland, tidal, and non-tidal habitats near or adjacent to the coast. Specifically, the following Delaware Wildlife Action Plan habitats are considered: beach and dune (overwash, foredune, grassland, inter-dunal wetland, shrubland, forests & woodlands); freshwater tidal (shorelines & mudflats, herbaceous, shrub, forested); peat wetlands (actidic fens); submerged aquatic beds (fresh and brackish); brackish tidal wetlands (herbaceous and shrub); tidal salt water wetlands (salt panne, high wetland, low wetland).

Exposure to Sea Level Rise: An analysis of the flora of Delaware, focusing on the habitats mentioned above (Table 19), found that a total of 631 native species of plants that typically occur within these habitats have the potential to be affected by sea level rise. This figure includes 172 that are state rare and uncommon (11% of the overall state native flora), 7 that are globally rare, and one that is listed as threatened by the U.S. Fish and Wildlife Service. In addition, 22 species that are at the northern limit of their natural geographic distribution and 9 species that are at their southern limit could be potentially affected by sea level rise. If these edge-of-range species, (the majority of which are freshwater species) were to become extirpated, then critical genotypes of the species will become extinct and the genetic diversity of the species will be degraded. Results specific to certain habitat types can be found in the spreadsheet below.

Potential Economic Impact: Unknown.

Potential Social Impact: Unknown.

Potential Environmental Impact: See discussion above.

Table 19 - Flora that may be affected by sea level rise and associated habitat type

ELAWARE WILDLIFE ACTION PLAN HABITAT	Total Taxa	53	51.1	52	53	Total Rare & Uncommon		G1, G2, G3	U.S.F.W.S Listed	Northern Limit	Southen
SEACH AND DUNE HABITATS	218	14		10	25		лога 26		Listed	Umit	Limit
Overwash, Foredune, Grassland, Interdunal	****			***	-			·			
Vetland, Shrubland, Forests & Woodlands)	ļ										
RESH WATER TIDAL											
Shorelines & Mudflats, Herbaceous, Shrub, orested)	170	15	3	15	7	41	24	4	0	6	4
PEAT WETLANDS (Acidic Fens)	122	4	2	21	15	40	33	1	0	5	2
UBMERGED AQUATIC BEDS (Fresh & Irackish)	35	5	0	3	5	13	37	0	0	0	2
BRACKISH TIDAL WETLANDS	54	6	3	3	4	13	24	0	0	4	0
Herbaceous and Shrub)											
in the second contract of the second											i a camarana i
TOAL SALT WATER WETLANDS	32	3	0	2	3	8	25	C	0	1	0
Salt Panne, High Marsh, Low Marsh)											
TOTALS	631	**	11		ro					22	فالتناسب

Conservation Status Ranks. S1: Extremely rare and of conservation concern; typically 5 or fewer extant occurrences or populations in the state; or only a few remaining individuals; may be especially vulnerable to extirpation. S1.1: To date, only a single extant occurrence or population of this species is known to exist in the state. S2: Very rare and of conservation concern; typically between 6 and 20 known occurrences or populations; may be susceptible to becoming extirpated. S3: Uncommon not of conservation concern; typically 21 to 50 known occurrences or populations. Global Status Ranks-C1: Critically imperiled globally because of extreme rarity (5 or fewer occurrences) or because of some factor(s) making it especially vulnerable. G2: Imperiled globally because of rarity (6-20 occurrences) because of some factor(s) making it especially vulnerable. G3: Either very rare or local throughout its range (21 to 100 occurrences), or found locally in a restricted range, or because of some other factor making it vulnerable to extinction throughout its range.

#### Native Fauna

Sea level rise impacts to Delaware's fish and wildlife species is a complex issue. Species have evolved to become dependent on habitats and habitat conditions over the millennia. As sea level rises, those habitats could be degraded or lost at a rate faster than species are able to adapt. Indeed, some of the species that are dependent on our coastal resources may already be experiencing population declines due to sea level rise. In particular, spartina high salt marsh (a habitat of conservation concern) harbors black rails, one of the rarest bird species both within the state as well as along the Atlantic coast. Black rail populations have declined by as much as 85% over the last twenty years and there is real concern for this species and its vulnerability to sea level rise. Greater than 99% of its habitat is predicted to be lost under the most conservative sea level rise scenario of 0.5 m by the 2100. This is just one of many examples of species that might be lost in the very near future.

Exposure to Sea Level Rise: Approximately 20% of the state's native fauna is considered rare and uncommon. Of the rare and uncommon species, 54% could be impacted at the 1.5 m sea level rise scenario which represents 11% of the entire state fauna. In addition, there are species that are currently considered common that may become rare or extirpated as a result of habitat changes from saa level rise. Therefore, 11% of the fauna is a conservative estimate of what could be impacted by sea level rise as this number only accounts for those species currently identified as rare and uncommon. Animals do have the ability to move and adapt with changing conditions and the bathtub inundation model used for this assessment does not take into account habitat that may be created or replaced. Regardless, sea level rise is anticipated to have significant impacts to our fauna. The level to which species populations will decline or become extirpated requires species-specific vulnerability assessments.

Potential Economic Impact: According to a report by the U.S. Fish and Wildlife Service, approximately one out of every three Americans over the age of 16 participates in wildlife watching. This has significant economic impact for Delaware where wildlife watching generates \$131 million in retail sales, \$77 million in salaries, wages, and business-owner income, and \$19.5 million in state and local tax revenue. It also creates 1,975 jobs within the state (Leonard, 2008). While these are state-wide figures, the economic impact from sea level rise would be significant considering that the habitats within the Delaware Bay coastal area are highly vulnerable to sea level rise and are a significant natural resource due to the extent and completeness of its ecological system.

Potential Social Impact: Sea level rise has the potential to result in significant social impacts as a result of wildlife population declines. Although not well understood, there is the possibility that the loss of species that help to control pest or pathogens associated with pests might increase disease transmission. Combined with a warming climate, more pests and pathogens that were once restricted to warmer tropical climates might become established in Delaware (Logan, Regniere, & Powell, 2003). Sea level rise may also impact harvested fish and wildlife to the extent that recreational or commercial hunting and fishing opportunities are no longer available. Finally, many people simply enjoy wildlife viewing. There may be physical and emotional consequences for individuals if opportunities to be outdoors and enjoy nature are limited. The loss of the salt marsh environment in Delaware, the most extensive natural system in the state, may have a negative impact on people and communities who can no longer utilize the habitat for flood attenuation, recreational or commercial purposes.

Potential Environmental Impact: The loss of just one species could be a significant environmental impact that has far reaching consequences. In most cases, it is unknown exactly what a species contributes to the environment around it or what ecological services it may provide. One example is control of pests and pathogens. However, there is also species inter-dependence. The loss of a nectar plant may extirpate a moth that then reduces food for another species and so on. If it were not for horseshoe crabs, red knots and other shorebirds may not find the food they need during a critical period of their life cycle.

#### Natural Resource Conservation Lands

This section of the assessment focuses on protected lands of conservation and recreational value. The first heading, Protected Lands Statewide, considers lands protected for various purposes and by various agencies. Of this broader category, two sub-heading of protected lands are discussed, Nature Preserves and National Wildlife Refuges. Nature Preserves are discussed because of the unique habitat types and significant ecological of these areas. The National Wildlife Refuges within the state, Bombay Hook and Prime Hook, are also of significant ecological value and represent a large portion of protected land in Delaware.

#### Protected Lands Statewide

Protected lands statewide are lands that are protected from development by a variety of different organizations and through a variety of different measures. They include state-owned properties such as wildlife areas, state parks, state forests, boat ramps, nature preserves, and historical sites. Protected lands also includes two federally-owned wildlife refuges, Bormbay Hook and Prime Hook. Municipal land holdings such as municipal parks, open space, and recreational facilities are also included. Privately-owned land with a permanent and legally binding conservation easement are also included. These easements prohibit future development and in some cases, limit the use of the land to specific purposes (like wildlife habitat) and are "held" by either a state or local government or private conservation organization. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation.

Exposure to Sea Level Rise: Sea level rise will bring changes to many of the places and amenities that people visit and enjoy in Delaware. Parks, natural areas and wildlife areas may lose ground to inundation and erosional forces, and wildlife populations may relocate or shrink as a result of changing habitats. Statewide, 37% to 44% of the state's permanently protected land could be inundated by sea level rise under the three planning scenarios (Table 20 Protected Lands (2009)). Geographically, these areas are concentrated in areas adjacent to the Delaware Bay in Kent and Sussex Counties (Maps in Mapping Appendix). Impacts resulting from sea level rise to these lands could affect the tourism industry and recreational opportunities in the first state.

Table 20 - Protected Lands (2009)

A	Total Acres	Total	Acres Inund	lated	Percent of Total Acres Inundated		
County	IOIAI ACIES	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	168,384	61,989	70,003	74,653	37%	42%	44%
New Castle	45,553	11,407	12,681	13,428	25%	28%	29%
Kent	54,399	30,289	34,336	36,388	56%	63%	67%
Sussex	68,433	20,294	22,986	24,837	30%	34%	36%

Source: DNREC- Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished

Potential Economic Impact: Outdoor recreation opportunities in Delaware are a large component of the tourism industry, as well as a way of life for Delaware residents. A 2006 national survey of wildlife recreation found that 395,000 people who live in or visited Delaware fished, hunted, or watched wildlife in the state. Of the total number, 159,000 people fished, 30,000 people hunted and 285,000 participated in wildlife-watching activities, which includes observing, feeding, and photographing wildlife (US DOI-FWS and US DOC-Census Bureau, 2006). During this time period, state residents and non-residents spent \$299 million on wildlife recreation in Delaware. Of that total, tirp-related expenditures were \$75 million and equipment purchases totaled \$204 million. The remaining \$20 million was spent on licenses, contributions, land ownership, and leasing, and other items (Caudill & Henderson, 2005). Inundation of the habitats within protected areas in the state may lead to a reduction in opportunities for fishing, hunting and wildlife-watching and a loss of the associated economic benefit of these activities.

Potential Social Impact: The social fabric of many of Delaware's small coastal towns is based upon fishing, boating, hunting, and other outdoor recreational activities. Reductions in the availability of these amenities as a result of sea level rise may affect tourism levels and local business revenues, leading to loss of business services and sense of community.

Potential Environmental Impact: The environmental impact is difficult to quantify as the lands discussed in this section represent various habitat types statewide. Reduction or loss of habitat within the protected lands can impact populations of the species that inhabit them. Wildlife may be forced to redistribute if habitats within the protected areas no longer meet their needs and may relocate to areas that are not afforded the same protection and management. Species that are unable to relocate may experience population decline.

Additional information about environmental impacts specific to nature preserves and national wildlife refuges are discussed in the following sections.

#### Nature Preserves

Nature preserves are relatively undisturbed protected lands, free from development pressure that thereby provide exceptional habitat for various species of flora and fauna. The designation of nature preserve is the highest level of land protection afforded by the State of Delaware. These lands are unique and often fragile environments that represent some of Delaware's most important natural habitats. There are currently 28 dedicated nature preserves composed of 65 tracts of both public and private land and water. The total acreage of nature preserves in the state is 4,774 acres.

Exposure to Sea Level Rise: Between 34% and 43% of the total acreage of natural preserves within the state could be inundated by sea level rise of up to 1.5 meters (Table 21). The level of exposure varies based on location and types of habitats within each nature preserve. Within New Castle County, there are four nature preserves that could lose up to half of their area as a result of inundation of up to 1.5 meters of sea level rise. One, Pea Patch Island, could be completed inundated by 1.5 meters of sea level rise. Kent County's Murderkill River Nature Preserve and Missillion Harbor.

Reserve could also be completely inundated with up to 1.5 meters of sea level rise. In Sussex County, there are eight preserves that could be impacted, one that is approximately 50% inundated (Nanticoke River Nature Preserve) and one that is marginally affected (Doe Bridge Nature Preserve). The percent of each nature preserve that could be subject to sea level rise is presented graphically in the Mapping Appendix.

Table 21 - Nature Preserves (2009)

Country	Total Acres	Total A	cres Inu	ndated	Percent of Total Acres Inundated		
County	rotal Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	4,774	1.633	1.874	2,031	34%	39%	43%
New Castle	1,626	414	482	512	25%	30%	32%
Kent	476	197	204	206	41%	43%	43%
Sussex	2,673	1,022	1,188	1,313	38%	44%	49%

Source: DNREC Division of Parks and Recreation, Nature Preserves (2009), unpublished

Potential Economic Impact: The potential economic impact from inundation of nature preserves is unclear.

Potential economic losses may come indirectly as a result of reduced ecotourism and associated dollars spent on lodging, food, etc. No economic data specific to nature preserves is available.

Potential Social impact: Loss of nature preserves as a result of sea level rise would deprive residents and visitors of access to these sites of ecological significance resulting in potential "quality of life" type social impacts and fewer passive recreation opportunities. It is essential that people retain the opportunities to maintain close contact with thriving ecological communities and environmental systems and to benefit from the scientific, educational, esthetic, recreational, and cultural values they possess. The benefit to the public is to have permanently protected unspoiled natural areas to enjoy.

Potential Environmental Impact: As stated above, nature preserves are unique and often fragile environments that represent some of Delaware's most important natural habitats. Sites selected for dedication as a nature preserve often have an outstanding vegetation community and habitat, species rarity, outstanding geological features or outstanding archaeological features. The environmental impact resulting from sea level rise is difficult to quantify as the preserves represent various habitat types statewide. In general, reduction or loss of unique habitats within the protected boundaries of the preserves can impact wildlife populations and plant communities. If habitats within the preserves no longer meet their needs, wildlife may relocate, sometimes to areas that do not afford the same protection and management that is provided by the nature preserve designation.

Additional Information: Detailed information on types of habitat loss may be available from data collected from each affected preserve. This data is likely available from the Natural Areas Program or may be captured under other land use data layers.

### National Wildlife Refuges

Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton, Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and visitors use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for consumptive wildlife uses such as hunting and fishing. In 2004, 63% of visitors to Prime Hook NWR were residents of Delaware; the remainder were visitors to the state. The vast majority of those visitors were there for non-consumptive (passive) outdoor recreation. Classes and school groups from area schools and colleges also use the refuges for environmental education programs.

Exposure to Sea Level Rise. The sea level rise inundation maps show that between 85-95% of the total acreage of NWRs in Delaware could be inundated by sea level rise (Table 22 USFWS Property). Up to 94% of the over 16,000 acres of marsh, forest and agricultural fields at Bombay Hook NWR could be inundated by sea level rise of 1.5 meters. Up to 98% of the habitats and land at Prime Hook NWR could be inundated by sea level rise of 1.5 meters.

Table 22 - USFWS Property

	Total Acres	Total	Acres Inund	ated	Percent of Total Acres Inundated		
County	of USFWS Property	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	25,266	21,354	23,478	24,120	85%	93%	95%
New Castie	0	0	0	0	0%	0%	0%
Kent	16,137	13,010	14,769	15,152	81%	92%	94%
Sussex	9,129	8,344	8,709	8,969	91%	95%	98%

Source: DNREC- Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished.

In addition to the results of the inundation maps that serve as the basis for this vulnerability assessment, the sea level rise risk for Bombay Hook NWR and Prime Hook NWR have been analyzed using the Sea Level Affecting Marshes Model (SLAMM). SLAMM analysis has limitations which are discussed in more detail within each specific SLAMM report (Scarborough, 2009). However, the results provide further indication of the magnitude of threat facing the two National Wildlife Refuges in Delaware and demonstrate the potential associated land cover changes.

For Prime Hook NWR, a SLAMM analysis was conducted by the Delaware Coastal Programs, utilizing SLAMM version 5 combined with more accurate elevation data than was typically relied upon for that version of the model (Scarborough, 2009). The model was applied utilizing inputs representing a range of possible future scenarios. It is anticipated that the reality could fall anywhere within these predicted outcomes. For example, under the 0.5 meter sea level rise scenario, if the model assumes that salt marsh accretion keeps pace with current sea level rise rates, and that there is full tidal influence along the coast, then the refuge is predicted to lose more than half of its marsh, and the amount of open water and tidal mudillat (combined) will more than quadruple. If the model assumes that salt marsh accretion will increase to 5.0 mm/year, keeping pace with sea level rise as salt marshes often can, then the reduction of marsh acreage is small and conversion to open water and tidal mud flat are not as pronounced. In both cases, more than half of the upland is predicted to be lost. The primary difference is whether or not the remaining areas are maintained in some form of wetland cover, or are converted to open water. Under each sea level rise and marsh accretion scenario, if the model assumes that coastal dunes will instead be maintained, these predictions do not change appreciably. Results for additional scenarios, such as increased rates of sea level rise, can be found in (Scarborough, 2009).

For Bombay Hook NWR, this effort was conducted in 2010 by a contracting firm on behalf of the USFWS Washington Office (Clough & Larson, 2010). Input values (e.g., elevation, sea level rise, accretion, erosion) were based on the available local or regional estimates. Under this analysis, Bombay Hook is predicted to lose more than three quarters of its regularly flooded (salt) marsh in scenarios higher than 1.0 meter. This model predicted that saltmarsh will increase with sea level rise scenarios less than 1.0 meter due to the conversion of irregularly flooded marshes. The refuge is predicted to lose between 23% and 62% of its upland, and between 15% and 97% of its irregularly flooded marsh across all scenarios. Maps of model results seem to predict that the refuge is fairly resilient to rates of eustatic sea level below 1.0 meter by 2100. However, there are concerns regarding the accuracy of the elevation data covering the refuge (Clough & Larson, 2010). New elevation data obtained during spring 2011 may allow for a new, more accurate, SLAMM analysis of Bombay Hook NWR.

Potential Economic Impact: Refuge management activities and influences contributing to the economy of the surrounding communities include Refuge purchases of goods and services within the local community, Refuge personnel salary spending, revenues generated by Refuge Revenue Sharing, and spending in the local community by Refuge visitors. The effects of sea level rise on Delaware's National Wildlife Refuges could have significant indirect economic impacts to the communities near the refuge, and thus to the state, from loss of recreational opportunities, and therefore loss of economic activity generated by recreation on Refuges. Potentially, changes in Refuge habitats could lead to changes in management that would alter other economic activities of the Refuges, but this cannot be estimated. For both Refuges, the "Banking on Nature" reports provide information on the economic input of the Refuge to the surrounding economy (Caudill & Henderson, 2005). This report examines expenditures by people visiting Refuges, and also calculates the "final demand" associated with each Refuge. Final demand is defined as the total spending by final consumers on all goods, in a given region, attributable to refuge visitation. Final demand includes spending by people who earn incorrefrom refuge visitors' activities as well as spending by refuge visitors themselves.

According to "Banking on Nature," the total visitor recreation expenditures for Bombay Hook NWR in 2004 were \$3,166,800, with non-residents accounting for \$3,009,800 (95 percent of total expenditures). Expenditures on non-consumptive activities accounted for 99 % of the total with hunting accounting for one percent. Total final demand was \$4,316,600. This is the total monetary value of economic activity generated in the 2-county area by refuge visitor spending. In turn, this final demand generated 37 jobs (both full-time and part-time) with total job income of \$1,387,400. Total tax revenue generated (county, state, and federal) amounted to \$855,000.

At Prime Hook NWR, "Banking on Nature" reports that visitor recreation expenditures in 2004 were \$1,043,600 with non-residents accounting for \$795,000, or 76%, of the total Refuge visitor recreational expenditures. Dollars spent by non-consumptive users totaled \$771,900, fishing expenditures accounted for \$222,100, or 21% of the total, and hunting expenditures totaled \$49,700, or 5% of total recreation expenditures. The final demand was calculated as \$1,456,000. This amount reflects the total monetary value of economic activity generated in the three counties of Delaware by Prime Hook NWR visitor spending. In turn, the final demand generated 13 jobs (both full-time and part-time) with a total job income of \$419,400. Total tax revenue generated (county, state, and federal) amounted to \$291,000.

At Prime Hook NWR, the Regional Economic Impacts of Current Management for the Refuge were also estimated using the "Impacts Analysis for Planning" (IMPLAN) regional input-output modeling system (Koontz, 2010), providing an updated refuge-specific report. Refuge management activities directly related to Refuge operations generate an estimated \$2.7 million in local output, 25 jobs, and \$742,000 in labor income in the local economy. Including direct, indirect, and induced effects, Refuge activities are estimated to generate total economic impacts of \$3.9 million in local output, 33 jobs, and \$1.1 million in labor income.

More specifically, non-consumptive uses (such as birding and general refuge visits) directly related to Refuge operations are estimated to generate \$2.1 million in local output, 21.3 jobs, and \$602,700 in labor income in the local economy. Including direct, indirect, and induced effects, on-consumptive uses are estimated to generate total economic impacts of \$3.1 million in local output, 29.3 jobs and \$875,000 in labor income. Fishing activities directly related to Refuge operations are estimated to generate \$180,4000 in local output, 1.8 jobs, and \$50,400 in labor income in the local economy. Including direct, indirect, and induced effects, fishing activities are estimate to generate total economic impacts of \$252,500 in local output, 2.1 jobs, and \$72,100 in labor income.

Overall hunting activities directly related to Refuge operations are estimated to generate \$73,500 in local output, 0.6 jobs, and \$21,000 in labor income in the local economy. Including direct, indirect, and induced effects, overall Refuge hunting activities are estimated to generate total economic impacts of \$103,600 in local output, 0.9 jobs, and \$30,100 in labor income. A further breakdown of hunting activities on the Refuge, including direct, indirect, and induced effects, reveals that big game hunting on the Refuge would generate total economic impacts of \$45,500 in local output, 0.4 jobs, and \$13,00 in labor income. Waterflow hunting on the Refuge is estimated to generate total economic impacts of \$60,000 in local output, 0.5 jobs, and \$16,600 in labor income. Small game hunting on the Refuge would generate total economic impacts of \$2,000 in local output, 0.5 jobs, and \$500 in labor income.

Impacts from sea level rise would likely result in a conversion of large areas of Refuges to different habitat types, and/or open water. The Refuges will still provide wildlife habitat, even if the nature of that habitat has changed, so, it is possible that outdoor recreation opportunities would remain. However, it is reasonable to expect that the quality or accessibility would be reduced, resulting in economic impacts for the nearby area.

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Potential Social Impact: Social impacts will stem from the loss of recreational opportunities, as well as from the loss of quality wildlife habitat. As described above, recreation at the Refuges provides significant and measurable economic benefit to the local economy by encouraging tourism from outside Delaware. The loss of such benefits will have considerable societal impact. Area residents, in particular, will suffer from the loss of a treasured natural area. Residents who use the Refuges for convenient source of recreation and a place to relax in the outdoors will be deprived of those opportunities, as access to the Refuges is likely to decrease following inundation. Regardless of how frequently they may visit, the mere presence of highly regarded National Wildlife Refuges in the area can be a sense of pride for some residents.

Far more difficult to quantify, but worth noting, is the loss of ecosystem services provided by the habitats, particularly the wetlands, that comprise both Refuges. These impacts are discussed in more detail under the assessment for each habitat resource (e.g., tidal emergent wetlands, forested wetlands). In summary, healthy wetlands provide a measure of flood protection by absorbing run-off from uplands as well as storm surge from the Delaware Bay. Healthy wetlands also improve water quality in areas downstream. The coastal wetlands of the Refuges, which are likely first to be inundated, provide important nursery habitat for fish species that are an important component of the local seafood economy. Indirect society impacts of inundation of these important ecosystem services provided by Refuge lands.

Potential Environmental Impact: National Wildlife Refuges are an incredibly important environmental resource in Delaware, and sea level rise is anticipated to have many significant environmental consequences. Both NWRs were established primarily for migratory birds, due to their position within the Atlantic flyway. Birds in various guilds concentrate at both Refuges at different stages of their life history. For example, both Refuges are important for migrating and overwintering waterfowl in the fall and winter, and for migrating shorebirds in the spring and late summer. Refuge wetlands also provide habitat for wading birds, secretive marsh birds, wetland passerines, and other landbirds. Reduction or loss of wetland habitats within the protected boundaries of the Refuges can impact populations of these species. They may be forced to redistribute if Refuge wetlands no longer meet their needs, and relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation.

Further details about the environmental consequences of the reduction or loss of specific habitat types found on the Refuges, especially wetlands, can be found elsewhere in this vulnerability assessment.

#### Agriculture

Agricultural land used in Delaware ranges from local crop and vegetable farms to large poultry producers and food processors. Support businesses, such as grain, fertilizer, and irrigation supply businesses, also fall in the agricultural use category. Many groups throughout Delaware benefit from the strength of the agricultural economy. State and local government agencies use funds generated by agricultural taxes to support other programs. This section discusses the potential impact from sea level rise on highly productive soils, agricultural preservation districts and conservation easements. The Society and Economy section of this document includes additional information about agricultural impacts.

### Highly Productive Soils

The category of highly productive soils includes prime farmland and farmland of statewide importance. Prime farmland is land which has the best combination of physical and chemical characteristics for the production of crops. It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to current farming methods. Prime farmland does not include publicly owned lands for which there is an adopted policy preventing agricultural use (NRCS). Farmland of statewide importance is land other than prime farmland which has a good combination of physical and chemical characteristics for the production of crops. Farmlands of statewide importance include those that are nearly prime farmland and that produce high yields of crops when treated and managed according to acceptable farming methods. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use (NRCS).

Exposure to Sea Level Rise: According to the inundation maps, exposure of highly productive soils to sea level rise are low, with only 2% to 4% of the highly productive soils potentially exposed under the three scenarios (Table 23 and maps in Mapping Appendix). An additional consideration is that highly productive soils data only considers the soil type; it does not consider whether or not the land area is used for agriculture. Localized impacts from sea level rise may be significant but would not likely negatively affect the state as a wholze.

Table 23 - Highly Productive Soils

	Total Acres	Total	Acres Inund	ated	Percent of Total Acres Inundated			
County	of Highly Productive Soils	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	693,128	12,564	22,699	32,361	2%	3%	4%	
New Castle	147,779	2,538	4,366	5,934	2%	3%	4%	
Kent	279,976	4,111	7,969	11,865	2%	3%	4%	
Sussex	265,373	5,916	10,364	14,562	2%	4%	5%	

Source: Delaware Coastal Programs, Prime Farmland (2011) and Farmland of Statewide Importance, unpublished

Potential Economic Impact: Prime farmland and farmland of statewide importance are the areas of Delaware where the highest crop production rates could occur (if the soils are in agricultural production). These soils are the state's economic drivers for agriculture; in 2009, net farm income was estimated at \$193 million (Awokuse Ilvento, & Johnston, 2010). Inundation of highly productive soils could render them unsuitable for agricultural purposes and decrease farming income to individuals and throughout the state, however, the percentage of highly productive soils potentially impacted is low and not all of these soils are in agricultural production. In addition to inundation, saltwater intrusion as a result of sea level rise could impact agricultural activities in general by decreasing crop yield, completely eliminating the capability of growing certain crops, and impacting the health of domestic livestock.

Potential Social Impact: Many communities in Delaware developed due to relative proximity to prime farmland. The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to relocate to areas not affected by sea level rise, causing losses to the local agricultural heritage of a community.

Potential Environmental Impact: Agriculture in Delaware often relies on irrigation which may be impacted by the intrusion of seawater pushing further up into fresh water stream and rivers. In coastal areas, the increased water withdrawal, combined with sea level rise, may increase saltwater intrusion into the groundwater or aquifers. Additionally, in agricultural locations near the coast, the seaward boundary for agriculture often is the point where saltwater penetrates inland far enough to prevent crops from growing (IPCC, 2007). As sea level rises, this boundary could move farther inland causing increased amounts of farmland to become too salty for traditional crop cultivation. Once seawater has invaded to a distance beyond that is tolerable, restoration of water quality in the invaded zone is generally an expensive or ineffective proposition. (Bear, Cheng, Sorek, Ouazar, & Herrera, 1999). Concerning prime farmland and farmland of state-wide importance, these soil types will lose their high production characteristics as salinity increases. The land may still allow for cultivation however, crop yields will begin to diminish well before inundation occurs.

# Preservation Districts and Conservation Easements

The Delaware Department of Agriculture implements a preservation program that uses two strategies to preserve farmland, agricultural preservation districts and agricultural conservation easements. A district is a voluntary agreement to use land only for agricultural purposes for at least a ten year period. Land must yield a minimum farm income, satisfy a scoring system standard, and undergo a review and approval process. Almost any size farm anywhere in the state can qualify. Permitted agricultural uses include but are not limited to: crop production, herd animal and poultry operations, horse operations, forest production, non-commercial hunting, trapping and fishing, and agricultural eco-tourism operations, as well as farm markets and roadside stands. In order to permanently preserve farmland, the development rights are purchased from landowners and a permanent agricultural conservation easement is placed on the land. Land must first be in an agricultural preservation district before the owner can apply to sell the development rights.

Exposure to Sea Level Rise: Approximately 8% -11% of acreage within Delaware's agricultural land preservation districts will be exposed to sea level rise (Table 24 and maps in the Mapping Appendix). The largest percentage of impact will be felt in New Castle County where 14% -16% of district farmland will be inundated under the 3 scenarios. Kent County has a similar range of 11% -16% of the total acreage impacted; however this percentage represents the largest acreage of impact within any of the counties. Impacts in Sussex County, where development has largely replaced farmland in coastal areas, range from 2% - 4% of the total district farmland.

Table 24 - Agricultural Land Preservation Districts

	Total Acres	Total	Acres Inund	ated	Percent of Total Acres Inundated			
County	of Land Preservation	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	55,907	4,307	5,281	6,218	8%	9%	11%	
New Castle	6,264	847	940	1,028	14%	15%	16%	
Kent	26,676	2,995	3,656	4,287	11%	14%	16%	
Sussex	22,967	464	685	904	2%	3%	4%	

Source: Del. Dept. of Agriculture, State Ag Easements, 2010-09-17

Approximately 13% - 17% of acreage of Delaware's agricultural land conservation easements could be exposed to sea level rise under the 3 scenarios (Table 25 and maps in the Mapping Appendix). Again, the largest percentage impact will be fet in New Castle County where 25% - 31% of preserved farmland within the county will be inundated. Kent County has a range of 14% - 19% of the total area impacted; however, this percentage represents the largest acreage of impact within the three counties. Impacts in Sussex County, where development has largely replaced farmland in coastal areas, range from 5% - 8% of the total farmland under conservation easement.

Table 25 - Agricultural Land Conservation Easements

	Total Acres	Tota	al Acres Inui	ndated	Percent of Total Acres Inundated			
County	Conservation	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	94,401	11,826	13,864	15,920	13%	15%	17%	
New Castle	11,693	2,950	3,317	3,652	25%	28%	31%	
Kent	52,139	7,334	8,532	9.687	14%	16%	19%	
Sussex	30,569	1,542	2,015	2,582	5%	7%	8%	

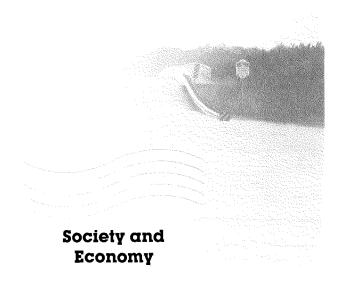
Source: Del. Dept. of Agriculture, State Ag Districts, 2010-09-17

Potential Economic Impact: As mentioned in the previous section, net farm income for Delaware was estimated at \$193 million in 2009 (Awokuse, Ilvento, & Johnston, 2010). Agriculture is a major driver of the state's economy. However, it is difficult to gauge the specific impacts to farms in the preservation program from sea level rise with the general information available for this assessment.

Potential Social Impact: Many communities in Delaware developed due to relative proximity to prime farmland. The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to relocate to areas not affected by sea level rise, causing losses to the local agricultural heritage of a community.

Potential Environmental Impact: Agriculture in Delaware often relies on irrigation which may be impacted by the intrusion of seawater pushing further up into fresh water stream and rivers. In coastal areas, the increased water withdrawal, combined with sea level rise, may increase saltwater intrusion into the groundwater or aquifers. Additionally, in agricultural locations near the coast, the seaward boundary for agriculture often is the point where saltwater penetrates inland far enough to prevent crops from growing (IPCC, 2007). As sea level rises, this boundary could move farther inland causing increased amounts of farmland to become too salty for traditional crop cultivation. Once seawarder has invaded to a distance beyond that is tolerable, restoration of water quality in the invaded zone is generally an expensive or ineffective proposition (Bear, Cheng, Screk, Ouazar, & Herrera, 1999). Concerning prime farmland and farmland of state-wide importance, these soil types will lose their high production characteristics as salinity increases. The land may still allow for cultivation however, crop yields will begin to diminish well before inundation occurs.

Additional environmental impacts may come from the loss of open space and actively farmed acreage which could result in habitat losses, decreases in water quality and increased erosion.



Properties with a tax-assessed value of nearly \$1.5 billion are located within areas potentially inundated by 1.5 meters of sea level rise (Laznik, 2012). The potential loss or devaluation of these properties will affect homeowners, businesses owners, communities, and tax revenues at all levels of government.

The Society and Economy Workgroup was formed to collaboratively investigate the potential effects of sea level rise on the residents, communities, and economy of Delaware. Its results are presented below and in the following sections. The socioeconomic effects of sea level rise issues are complex and interrelated; the Society and Economy Workgroup recognizes that the information that has been gathered and presented through this vulnerability assessment process is not complete in many cases; much more research will need to be conducted to answer many of the questions posed by the workgroup in its discussions.

### Assessing Exposure of Society & Economy Resources

The Society & Economy Workgroup was composed of members of the Sea Level Rise Advisory Committee and additional subject matter experts. A list of those who participated in this workgroup is available in Appendix C. The workgroup met seven times between February 2011 and March 2012 to identify, assess, and rank issues related to sea level rise, society, and the economy.

#### Resources Considered

Specific resources that the Society and Economy Workgroup was initially concerned with included:

- Municipalities and future development areas
- Residences
- Businesses
- Tourism
- · Real estate taxes
- Insurance claims
- Agriculture, including highly productive soils and easements
- Demographic information and vulnerable communities
- Historic resources
- · Impermeable surfaces
- Hospitals
- Day care facilities
- fire and EMS stations
- Wastewater infrastructure
- Landfills

After discussion, initial data collection, and analysis by Delaware Coastal Programs staff,

the workgroup narrowed their focus to the following topics:

- Businesses
- Industrial and manufacturing facilities
- Residences
- Future development areas
- Agriculture (acreage and structures)
- Tourism and coastal recreation
- Historic and cultural resources
- · Socially vulnerable communities

Several resources of concern were initially identified by more than one workgroup, including agriculture, care facilities, wastewater, and landfills. Agriculture acreage and buildings were assessed in the Society and Economy Workgroup because of the strong economic implications of these resources. Conversely, the Natural Resources Workgroup assessed highly productive soils and agricultural preservation areas due to their stronger resource implications. Hospitals, day care facilities, emergency services, wastewater infrastructure, and landfills were assessed in the Public Safety and Infrastructure Workgroup.

#### Assessing Exposure

As described in the Vulnerability Assessment Methods chapter, Delaware Coastal Programs staff worked with Workgroup and Committee members to collect data and information about each resource that the workgroup wished to assess. Using available data sets, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. All of this information was compiled together into a comprehensive assessment for each resource, which was reviewed and edited by workgroup members. Full text of each one of these assessments follows this introduction.

### Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a statewide level screening of resources at risk to sea level rise. In many cases, data and information that would have provided a better picture of the economic and social ramifications of sea level rise impacts was not available at a scale that would be useful for analysis of sea level rise. For example, tourism data is available statewide, but not broken down by town or region, so definitive conclusions about inundation of certain areas of the state could not be made. This is also the case for employment, payroll, and sales revenue data which is not available at a site specific basis. Demographic information was also not available at a scale that would allow site specific assessments of very small areas of inundation due to sea level rise. These data gaps do limit our ability to provide specific economic losses and social ramifications for each resource assessed. However, they do not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts.

#### Property Tax Impact

As discussed above, data and information useful for understanding the wide range of interrelated economic impacts resulting from sea level rise was not available and additional studies are recommended. One readily available dataset is the tax assessment value. A study conducted by the University of Delaware indicated that the current tax assessed value for all parcels (regardless of use category) exposed to sea level rise in New Castle County is \$582 million and \$55.6 million in Kent County. The assessed "improved value" of parcels exposed to sea level rise in Sussex County is \$65.7 million (Laznik, 2012). Although tax rates per assessed value vary by county and some parcels have tax-exempt status, properties that are abandoned, de-valued or inundated could have an impact to local property tax revenues.

#### Assessing Vulnerability of Society & Economy Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Society and Economy Workgroup conducted an exercise to assess the state's vulnerability to the effects sea level rise for each resource. Using standardized questions, the workgroup considered two primary factors: the geographic scope of impacts and whether the resource could continue to "function". For geographic scope, the workgroup considered both the discrete locations of impacts themselves and the extent to which impacts may be felt outside of those locations. For example, although the exposure of heavy industrial areas was limited primarily to New Castle County, the effects of exposure could be felt statewide through loss of job opportunities and revenues. For "function," the committee considered the extent to which a resource could continue to meet its intended purpose, whether that purpose is recreational opportunities, manufacturing items and/or revenue generation. As a result of this discussion, each resource was ranked as a High Concern, Moderate Concern, Low Concern, or Minimal Concern. Resources ranked as a high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

#### High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: Heavy Industrial Areas, Future Development Areas, and Tourism & Coastal Recreation. A high concern resource is generally a resource where inundation of a resource would cause it to no longer function and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruptions in jobs or revenue streams. Additional research and development of adaptation strategies for high concern resources is recommended.

Heavy Industrial Areas: Between 16% and 25% of the acreage of heavy industrial lands in the coastal area (as permitted by Delaware's Coastal Zone Act) are within an area that could be inundated by sea level rise by 2100; the majority of these areas are in New Castle County. While the inundation model shows that inundation risk to the facility buildings themselves is low, many associated structures like docks, piers, and lagoons could be affected. Because these facilities are a large economic driver for the state, reduced operational capacity could impact both the economies of the towns surrounding these facilities and the state's economy as a whole. If the lands currently zoned for heavy industry become unsuitable for industrial operations, retaining these businesses within the state could prove difficult due to lack of suitable industrially zoned land and the difficulties of rezoning land to industrial uses. Due to the significant potential statewide effects, sea level rise impacts to heavy industrial areas in the state were renked as a high concern.

Future Development Areas: Between 3% and 7% of land designated as future development areas by Delaware's Strategies for State Policies and Spending are within an area that could be inundated by sea level rise by 2100. These areas are typically rural or suburban in nature and are adjacent to the actively growing zones of Delaware's municipalities. Four-fifths of these potentially inundated areas are located in Sussex County and could be developed to meet the future demand for residential and commercial development in and around the resort areas. Careful consideration must be given to determine whether directing new development to potential inundation areas will place citizens and infrastructure at risk in the future and whether creating new building restrictions will impact citizens' freedom of choice and the regional economy. Due to the significant potential effects for development in Sussex County coupled with the potential need for state funding of infrastructure repairs and legal concerns, sea level rise within future development areas was ranked as a high

Tourism and Coastal Recreation: Tourism and coastal recreation are important components of Delaware's economy and quality of life. Significant portions of Delaware's resort areas, coastal historic sites, and natural resources could be inundated or significantly altered by sea level rise. Of specific concern is the maintenance of Delaware's beaches, which are currently replenished on a routine basis with federal and state funding. Accelerated rates of sea level rise may necessitate larger or more frequent beach replenishment projects to preserve recreational beach uses. Due to the potential for revenue losses statewide, coupled with the potential increased funding needs for maintenance or repair of tourist destinations, sea level rise impacts to tourism and coastal recreation were ranked as a high concern.

#### Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup, only residential areas were categorized as having moderate concern. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impact is less than statewide.

Residences: Statewide, 1% to 5% of residences are within an area that could be inundated by sea level rise by 2100. The highest concentration of those at risk homes are in Sussex County, along the barrier island south of Bethany Beach and around the Inland Bays. Although the majority of at-risk residences are in Sussex County, residences within small coastal towns in Kent County are at risk of inundation from sea level rise, as are homes in the cities of Wilmington, New Castle, and Delaware City. In already flood-prone areas, some of these homes may be elevated above the current 100-year flood zone or have other flood-proofing mechanisms installed which would limit structural damage from sea level rise. However, road access to homes subject to inundation may be limited whether the homes are flood-proofed or not. Several impacted residential areas are within socially vulnerable communities (see below) and may lack resources to repair flood damages, flood-proof, or relocate. Because potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to residential addresses were ranked as a moderate concern.

#### Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Businesses and Commercial Areas, Agriculture (acreage and structures), Historic Resources, and Factories. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts will not be significant in nature and/or will be isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Businesses and Commercial Areas: Between 1% and 5% of the state's commercial addresses are within an area that could be inundated by sea level rise by 2100. The effects to impacted businesses could include increased flood damage costs, increased insurance premiums, and reduced profitability; indirect impacts could include reduced employment opportunities and reduced goods and services for communities impacted. However, the business cycle may minimize these potential impacts as the life-span of most business ventures is much shorter than our planning horizon of 88 years and adequate commercially zoned land is likely to exist outside of the sea level rise inundation areas in the future should business owners need to relocate. While the overall impact to the state's businesses may be a small percentage, Delaware's commercial fishing and seafood industry may be particularly affected by loss of supporting infrastructure like docks and boat ramps and potential challenges to fish populations. In addition, individual business owners who rely upon waterfront access or proximity to the coast may be particularly impacted. Because of the small percentage of potentially impacted businesses and because the life-span of most commercial areas are of low concern at this time.

Agriculture (acreage and structures): Between 1% and 4% of currently farmed acreage in the state could be inundated by sea level rise by 2100. Inundation of agricultural land could result in decreased crop yields as a result of salt contamination and/or soils that are too wet to till. While the loss of a few thousand acres of tillable land is not likely to have a perceptible impact on the state's agricultural economy as a whole (residential development takes more land out of agricultural production), impacts to individual or regional agribusinesses could be significant. Because of the small percentage of potentially impacted land statewide, sea level rise impacts to agriculture are of low concern at this time.

Factories: Between 1% and 8% of industrial and manufacturing facilities in the state (as represented by sites listed on the toxic release inventory) are within areas that could be inundated by sea level rise. These facilities could experience repetitive flood damages, supply disruptions, and reduced production as a result of sea level rise. While facilities may experience effects of sea level rise, existing plants could become functionally obsolete during our planning horizon. Because of the small number and limited life-span of potentially impacted factories, sea level rise impacts to manufacturing and industrial facilities are of low concern at this time.

Historic Resources: Between 2% and 4% of the known historic sites (including up to 32 national historic register sites) in the state are within areas that could be inundated by sea level rise. Inundation could result in the permanent loss of these sites and their cultural value, including loss of historic information that could have been gamered from them. Because of the relatively small number of buildings at risk, historic resources are of low concern at this time.

#### Social Vulnerability and Social Justice

Throughout the deliberations of the Society and Economy Workgroup, issues of social vulnerability and social justice were discussed and considered. Socially vulnerable communities are neighborhoods or groups that are less likely to have the resources to respond to environmental threats like sea level rise due to a variety of factors including educational level, economic standing, age, family status, and access to services. Citizens in areas identified as socially vulnerable may lack the resources to flood-proof their homes or relocate if sea level rise begins to affect their neighborhood. They may also lose access to transportation should bus routes or bus stops be relocated due to road flooding in the region; this could also affect their ability to travel to and from work. In addition, these communities are often near or within areas of already poor environmental quality and may disproportionally be affected by indirect impacts of sea level rise such as contaminant releases from underground storage tanks or contaminated sites.

A detailed sub-chapter on socially vulnerable populations is included within this document (pg. 2) but this issue was not ranked with the other resources analyzed in this document because assessment of these communities will need to be conducted at a more localized scale and with consideration of the interaction of numerous direct and indirect sea level rise impacts. Attention to and the fair treatment of socially vulnerable communities should be at the forefront in the minds of decision-makers as plans are made to adapt to the effects of sea level rise.

#### **Detailed Resource Assessments**

The following sections contain a detailed exposure assessment for each resource and a description of the likely economic, social, and environmental impacts that could result. As discussed in the Introduction to this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios; not whether that resource will be impacted. For example, a house that has been elevated above the floodplain is counted within the sea level rise inundation area, but that particular house may be unaffected by sea level rise because it has been flood-proofed. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

#### **Businesses and Commercial Areas**

Commercial business enterprises form the backbone of Delaware's economy, communities, and sense of place. Many of Delaware's towns were established in waterfront locations to take advantage of shipping opportunities, and many business districts in Delaware remain in close proximity to tidal water.

Businesses within areas potentially inundated by sea level rise may experience increased operational costs as a result of repetitive flood damage and reduced access for customers and product shipments as a result of flooded roads. In addition, businesses dependent upon waterfront access may experience increased costs for dock and pier maintenance and upgrades as well as a lack of adequate space for operations as water encroaches inland. Although many businesses can relocate when lease terms end and so may be resilient to the effects of sea level rise, waterfront and water-dependent businesses, like commercial fishing operations and marinas, may not have as many choices when deciding how to respond to the effects of sea level rise.

As demonstrated by several large coastal storms, temporary flooding causes little or no long term disruption to businesses if an area is economically viable. If more permanent inundation occurs as a result of sea level rise, history indicates that human populations have been able to adapt to these changes by moving to higher ground over a period of time. These potential impacts will depend greatly upon a business's ability to adapt to new conditions, the maintenance of supporting infrastructure and upon availability of suitably zoned areas to relocate if necessary.

Exposure to Sea Level Rise: In order to determine the potential vulnerability of Delaware's businesses to sea level rise, two data sources were used, the statewide 911 address database and the Delaware Division of Revenue's business license database. The 911 address database provides address information by type of address, including commercial. The state business license database provides an address for business licenses that are issued within the state. Both databases contain inherent errors and inaccuracies. For example, the commercial addresses from the 911 database include rental properties, which are also residences. The business license database contains addresses that were not able to be mapped in our computer system, which may underestimate the number addresses affected. Conversely, some addresses have multiple businesses licenses in one location, which may overestimate the number of addresses affected. Fixing the inherent data problems within these datasets was outside of the scope of this assessment; however, using both of these databases together provides a reasonable estimate of the extent and location of potential impacts to businesses resulting from sea level rise (see Table 26 and Table 27 below).

Statewide, over a thousand individual businesses are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% - 3% of the total businesses in the state. Over two thousand businesses are within an area that could be inundated by 1.5 meters of sea level rise, representing about 5% of the total businesses in the State. Sussex County has both the highest number and highest percentage of businesses at risk, with between 9% - 11% of its businesses within a mapped sea level rise area.

At the 0.5 meter sea level rise scenario, the highest concentration of businesses with the potential to be inundated is found in South Wilmington, New Castle, Milton, and Fenwick Island. At higher levels of sea level rise, the geographic extent of businesses potentially inundated expands to include Delaware City, Dover, Milford and more areas along the Delaware Bay and Inland Bays (see maps in the Mapping Appendix).

Further evaluation of the types of businesses affected and their average life-spans, employment figures, and revenue figures are outside of the scope of this vulnerability assessment, but the Sea Level Rise Advisory Committee recognizes the importance of obtaining and analyzing this data for a more comprehensive understanding of potential business impacts from sea level rise.

Table 26 - Number of Commercial Addresses

County	Total Number	Total Addresses Inundated			Percent of Tota Inundated		
	of Addresses	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	45,873	395	1,182	2,094	1%	3%	5%
New Castle	31,479	248	625	1,143	1%	2%	4%
Kent	4,714	21	73	93	< 1%	2%	2%
Sussex	9,680	126	484	858	1%	5%	9%

Source: University of Delaware CADSR 9-1-1 Address Database

Table 27 - Number of Business Licenses within the Sea Level Rise Scenario Areas

County	Total Number	Total Bus. Liscenses Inundated			Percent of Total Inundated		
	of Licenses	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	51,302	237	1,072	2,556	0.5%	2%	5.%
New Castle	29,258	120	349	777	0.4%	1%	3%
Kent	8,823	14	149	323	0.2%	2%	4%
Sussex	13,221	103	574	1,456	0.8%	4%	11.0%

Source: Delaware Division of Revenue and University of Delaware CADSR.

Potential Economic Impact: For property owners, sea level rise may result in increased costs of maintaining existing commercial structures whether from repetitive flood damages or flood-proofing measures. Other associated costs of doing business, like insurance premiums, may also rise. Costs for construction of a new business or redevelopment of an existing business could also rise as a result of decreased availability of coastal real estate or costs of complying with regulations.

On a regional scale, a reduced number of businesses or reduced profitability of businesses impacts business revenues, business reinvestment, and employment opportunities. It may also affect local and regional tax revenues.

The commercial fishing and seafood industry in Delaware may be particularly impacted by sea level rise. In 2009, this industry employed 407 people, creating \$57 million dollars in sales. The total economic impact of recreational fishing the same year as measured by fishing trips and durable equipment expenditures was 1,270 jobs and \$193 million in sales (National Marine Fisheries Service, 2010). The commercial fishing fleet is located primarily in small coastal towns and inlets in Kent County, with additional sites in Indian River and Cedar Creek (near Slaughter Beach). These places are within areas expected to experience inundation with 0.5 meters of sea level rise; additionally, salt-water intrusion could result in degradation of fish spawning grounds, leading to a reduction in the abundance of commercially important fish species.

Potential Social Impact: The potential social impact of commercial property exposed to sea level rise includes, but is not limited to: loss of employment centers and opportunities, loss of gathering locations for the public, potential reduction in local businesses and small town charm, and potential increase in travel distance for basic necessities. These potential social impacts will depend greatly upon the business's rental or lease agreements and ability to adapt to new conditions.

Potential Environmental Impact. The potential environmental impacts associated with commercial properties and structures exposed to sea level rise primarily include release of contaminants, coastal debris, and loss of natural shorelines.

Pollution and release of contaminants may occur if commercial properties are abandoned without first removing underground or above ground storage tanks or remediating historic soil contaminants. Over time, storage tanks may leak, leaching their contents into the surrounding area. Certain contaminants in soil can also be released into the water column if repeatedly or permanently inundated. In addition, any structure left on a property that is subject to routine flooding may be transported off-site, and become a hazard or nuisance to surrounding landowners.

The hardening of natural shorelines in response to increased inundation is a concern for both commercial and residential properties. Natural, vegetated shorelines provide fisheries habitat, bird foraging areas, and water quality improvements. Natural shorelines in commercial and residential areas can erode as a result of rising sea levels coupled with boat wakes and wave action and landowners may wish to build a stone revetment or builkhead to avoid additional erosion. When natural shorelines are replaced by hard structures, habitat and water quality benefits decrease significantly.

### Industrial and Manufacturing

Delaware has a rich history of industrial and chemical manufacturing, beginning with the DuPont family who manufactured gunpowder along the banks of the Brandywine River in the 1800's. Since that time, Delaware's economy and quality of life have been closely tied to industrial and chemical manufacturing and processing. Industrial and manufacturing facilities provide jobs for Delaware residents, goods for the region, and tax revenue for state and local governments. The Bureau of Labor Statistics reports that production occupations (largely those from industrial and manufacturing facilities) accounted for

20,709 jobs in Delaware as of May, 2010. These jobs have a mean annual salary of \$32,810 (Bureau of Labor Statistics, 2010).

Many of Delaware's largest industrial and chemical manufacturing facilities are located along the Delaware River and generally require direct access to navigable water for docking of ships carrying materials and supplies, or export of manufactured products. Many also rely on the Delaware River for cooling water or to discharge treated effluent. These facilities are large economic drivers for Delaware; for example, a 2002 analysis of the Motiva Refinery in Delaware City (now Delaware City Refinery) found that the refinery had a wage and salary impact of \$186 million per year, and a total economic impact of \$379 million per year (Condiffe, 2002).

The location of waterfront heavy industry in Delaware is limited to areas that were already in industrial use prior to the passage of Delaware's Coastal Zone Act, which prohibited new industrial development in the Coastal Zone, a strip of land generally east of Route 13 in New Castle County, Route 9 in Kent County and Route 1 in Sussex County. It also includes land along the Chesapeake & Delaware Canal, and around Delaware's Inland Bays.

Sea level rise can affect Delaware's industrial and manufacturing facilities in several primary ways. Rising sea levels could permanently inundate facilities and supporting infrastructure like parking areas, wastewater lagoons and storm-water treatment areas. Temporary flooding from coastal storm events could also damage these structures. Increased rates of shoreline erosion could also occur, coupling with rising sea level to cause structural issues for associated docks and piers.



Map 1 - Delaware Coastal Zone Industrial Area.

In addition, the structure and function of intake and discharge pipes could be impacted either through increased water levels, increased salinity, or a combination of both.

Exposure to Sea Level Rise. To assess impacts to waterfront industrial areas, a database containing parcel information for permitted industrial facilities under the Coastal Zone Act was obtained from DNREC. This database contains the name, location, and property boundaries of each industrial facility within the areas regulated by the state's Coastal Zone Act. All major waterfront industrial facilities are included in this database. This database was analyzed to determine the acreage and location of permitted industrial facilities within the three sea level rise scenarios (Table 28).

Statewide, approximately 20% of the land comprising the facilities permitted by the Coastal Zone Act is within an area potentially inundated by sea level rise of 1.0 meter, a total of 781 acres. However, although industrial land is exposed to sea level rise, it is important to note that there are no industrial facility buildings within the three future sea level rise inundation areas.

In New Castle County, approximately 19% of the acreage permitted under the Coastal Zone Act is exposed with a sea level rise of one meter. At this level of sea level rise, docking facilities at Sunoco, Ocean Port and DuPont Edgemoor are exposed, as is a limited area of shoreline. Intake and/or discharge pipes and channels could also be affected at these facilities, as well as the Delaware City Refinery and Croda/Atlas Point. The remainder of impacts to lands within these facilities is wellands and in some cases, parking areas.

There is only one heavy industrial facility permitted under the Coastal Zone Act in Kent County; Delaware Storage and Pipeline, a dock and tank facility where jet fuel is delivered. In this case, the dock, pipeline and tank facility are almost entirely injundated under the 0.5 meter scenario, as is the road to the site.

The Indian River power plant is the only heavy industrial facility permitted by the Coastal Zone Act in Sussex County. This facility's disposal area, shoreline, and intake structures are within areas that will be inundated by sea level rise, but the power plant itself is not within a potential inundation area.

Table 28 - Coastal Zone Heavy Industrial Acreage Exposed to Sea Level Rise

County	Total Acres	Total	Total Acres Inundated			Percent of Total Acres Inundat			
	of Industrial Land Permitted by CZA	0.5 m	1.0 m	1.5 m	0.5 m 1.0 m	1.5 m			
State	4,141	676	863	1,041	16%	21%	25%		
New Castle	3,861	583	746	913	15%	19%	24%		
Kent	37	30	36	37	83%	97%	100%		
Sussex	243	63	81	91	26%	33%	38%		

Source: DNREC Office of the Secretary, Coastal Zone Heavy Industrial Facilities (20110321), unpublished

To capture potential exposure from sea level rise at facilities that are not considered to be heavy industry in addition to those permitted through the Coastal Zone Act, a database containing names and locations of facilities which are required to report emissions to the state through the Toxic Release Inventory was obtained and overtaid with the sea level rise scenarios. Because the geographic location in this database is reported as a "point" instead of as a parcel, the results of the analysis more closely aligns with potential exposure to a facility or building (instead of to the parcel). This data also contains information for those facilities permitted through the Coastal Zone Act, but is more inclusive of smaller industrial and manufacturing facilities, and those not within the Coastal Zone Act area (such as facilities along the Nanticoke River).

Statewide, one facility is located in an area potentially inundated at 0.5 meters, six facilities are within an area inundated at 1.0 meter and twelve facilities are potentially inundated with a sea level rise of 1.5 meters (Table 29). The geographic extent of these potential impacts is limited to Wilmington and the surrounding area, Lewes, and Seaford (see map in the Mapping Appendix).

Table 29 - Number of Factories (as represented by Toxic Release Inventory sites)

County	Total Number	Total Factories Inundated			Percent of Total Inundated			
	of Factories	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	145	1	6	12	1%	4%	8%	
New Castle	85	1	4	8	1%	5%	9%	
Kent	26	0	0	0	0%	0%	0%	
Sussex	34	0	2	4	0%	6%	12%	

Source: EPA, EPA Facilities Toxics Release Inventory, 20080212

Potential Economic Impact: Direct loss of land acreage zoned as industrial as a result of inundation from sea level rise or as a result of access or transportation issues resulting from sea level rise could constitute a significant economic issue for the state. Industrial facilities are an important component of Delaware's statewide economy; moreover, land zoned as industrial with access to water and rail is a limited resource in the state. Should industrial acreage be inundated, there is limited potential for zoning new areas for industrial use within the state due to siting issues related to environmental, noise, and traffic concerns.

Operators of industrial and manufacturing facilities could experience increased costs from repetitive flood damage to buildings and associated structures, costs to relocate or elevate docking facilities, costs to relocate or raise intake/discharge pipes and increased insurance costs.

The Delaware Department of Labor reported 25,400 manufacturing jobs in the state as of March, 2012. If facilities were to shut down or reduce operations due to inundation and have no place to relocate, there could be a loss of employment and associated state and local tax revenues. Jobs within the industrial/manufacturing sector are often well paid, and have multiplier effects within the community and region.

From a regional perspective, it is also possible that a loss of one major sector or client to a railway company could result in a rail-line being financially unviable, resulting in the loss of that transportation network for other smaller users.

Potential Social Impact: Reduction in operational capacity of the industrial and manufacturing sector in Delaware from the effects of sea level rise could result in the loss of well-paying jobs in the affected communities listed above, and may also result in migration out of those locations as people search for new employment opportunities. Lack of local customers could also impact the surrounding local businesses and service providers in those communities.

Potential Environmental Impact: The potential environmental impacts associated with commercial properties and structures exposed to sea level rise primarily include release of contaminants and loss of natural shorelines.

As industrial land is inundated, there is the potential for contaminants contained within soil to be released into the water column. This is a concern for both existing facilities as well as for facilities that have been shut down or abandoned (see Public Safety and Infrastructure Section for additional details regarding brownfield and hazardous waste sites).

The hardening of natural shorelines in response to increased inundation may also occur in industrial or manufacturing areas. Natural, vegetated shorelines provide fisheries habitat, bird foraging areas and water quality improvements. Natural shorelines in industrial or manufacturing areas can erode as a result of rising sea levels coupled with boat wakes and wave action; facilities may wish to build a stone revetment or bulkhead to avoid additional erosion. When natural shorelines are replaced by hard structures, habitat and water quality benefits decrease significantly. However, industrial shorelines are often already severely degraded. The extent of habitat impact will vary dependent upon a facilities particular location and shoreline use.

#### Residences

Delaware is home to nearly 900,000 people, living in 325,000 households, primarily owner-occupied (74%) (US Census Bureau, 2012). Between 2000 and 2010, Delaware's population increased by 15%, and many regions experienced unprecedented growth, particularly Southern New Castle County and Eastern Sussex County. Many of the residential construction projects that were planned during this time have stalled or have been abandoned due to the financial credit crises.

Sea level rise can affect housing units and residential communities through increased storm damage, permanent inundation of lots and through degradation of supporting infrastructure like roads, septic systems, and sewer systems (please see the Public Safety and Infrastructure Section of this document for more information on these impacts). Many newer subdivisions were established with community open spaces and stormwater facilities, managed and maintained by a maintenance corporation composed of residents. Sea level rise may also impact these community facilities in a similar way.

### Exposure to Sea Level Rise

In order to determine the number of homes located within a potential inundation area, the Delaware 911 database was used. This database provides a point for each residential address in the state, whether it is an apartment building, a townhouse, a manufactured home, or a single-family home. Although every point in the database does not necessarily fall exactly on a structure, this database provides a reasonable estimate of potentially affected structures at the state level.

Results of this analysis (Table 30) indicate that 1% of the residential units in the state are within the 0.5 meter inundation area and that 5% are within the 1.5 meter scenario. Although this is a small percentage statewide, it represents potential impacts to between 4,000 and 20,000 residences within our state. Geographically, potential impacts to residences are clustered in developed areas, particularly coastal towns and the areas surrounding the Inland Bays (See maps in the Mapping Appendix).

In New Castle and Kent Counties, the potential number of housing units affected is very small (in most cases less than 1%), regardless of type (single-family, multi-unit or manufactured). A higher percentage of the total housing stock in Sussex County is within potential inundation areas than in either Kent or New Castle, largely due to the different development patterns in the resort areas which have resulted in high density residential development close to tidal water. Bethany Beach, South Bethany and Fenwick Island and the areas surrounding the Assawoman Bay have the highest concentration of potential residential impacts in both Sussex County and the state. The address data did not allow us to discern how many structures were second homes or seasonal rentals.

Table 30 Residential Addresses affected by sea level rise

County	Total Number	Total Addresses Inundated			% of Total Addresses Inundated		
	of Addresses	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	346,574	3,571	9,988	17,095	1%	3%	5%
New Castle	166,569	131	409	923	< 1%	< 1%	1%
Kent	60,010	140	500	824	< 1%	1%	1%
Sussex	119,974	3,300	9,079	15,348	3%	8%	13%

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Table 31 Number of Residential Multi-Unit Addresses Exposed to Sea Level Rise

County	Total Number	Total Addresses Inundated			% of Total Addresses Inundated		
	of Addresses	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	46,777	119	243	328	<1%	1%	1%
New Castle	37,022	۵	0	12	0%	0%	<1%
Kent	1,770	0	0	0	0%	0%	0%
Sussex	7,985	119	243	316	1%	3%	5%

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Table 32 Number of Residential Manufactured Home Addresses Exposed to Sea Level Rise

County	Total Number	Total Addresses Inundated			% of Total Addresses Inundated			
	of Addresses	0.5 m	1.0 m	1.5 m	0.5 m	0.5 m 1.0 m		
State	18,526	350	2,201	3,318	2%	12%	18%	
New Castle	3,772	0	0	0	0%	0%	0%	
Kent	4,485	0	0	3	0%	0%	<1%	
Sussex	10,269	350	2,201	3,315	3%	21%	32%	

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Potential Economic Impact. Homeowners, property managers, and community associations could experience increased costs from repetitive flood damage to homes and associated structures and increased insurance costs. In some severely affected areas, property values could eventually decrease as structures become more difficult to access or experience frequent flooding and as surrounding homes are abandoned.

A study conducted by the University of Delaware indicated that the current tax assessed value for all parcels (regardless of use category) exposed to sea level rise in New Castle County is \$582 million and \$55.6 million in Kent County. The assessed "improved value" of parcels exposed to sea level rise in Sussex County is \$857.7 million (Laznik, 2012). Although tax rates per assessed value vary by county and some parcels have tax-exempt status, properties that are abandoned, de-valued or inundated could have an impact to local property tax revenues.

The availability and cost of flood insurance and homeowner's insurance for residences in areas exposed to sea level rise is also a significant economic consideration. Forty-seven communities in Delaware participate in the National flood insurance Program (NFIP), which makes federally-backed flood insurance available the residents through the Federal Emergency Management Agency (FEMA). In order to participate, communities are required to adopt at least the minimum floodplain regulations and sign a resolution to adopt and enforce these regulations. Private (not federally-subsidized) flood insurance is also available to communities that do not participate in the program, and in coastal areas where the NFIP is prohibited from writing flood insurance policies by the Federal Coastal Barrier Resources Act. While sea level rise is not in itself a peril covered by the NFIP, the impacts of sea level rise related to higher flooding levels during storms may be felt by property owners and would be lessened by the continued availability of flood insurance.

Recently, the NFIP has been financially strained due to devastating storms, leading to speculation that fundamental changes are needed to make the NFIP financially solvent. At the same time, NFIP insurance premiums have increased annually by 10% each year, the maximum increase allowed by law. A few insurance companies have periodically stopped writing new homeowners' insurance policies in coastal Delaware, but this is not due to flood risk; rather it is because their dense portfolio of policies in the region exposes them to unacceptable levels of payout in one weather event.

Potential Social Impact: The potential social impact to residential structures and property exposed to sea level rise largely depends on the type of adaptation measure(s), if any, that are employed. A significant amount of the residential property exposed to sea level rise is in small coastal towns along the Delaware Bay and InalO Bays as well as in Delaware City, the town of New Castle, and South Wilmington. As a result of both an increase in existing residential development and future residential development land exposed to sea level rise, the quality of life, neighborhood fabric, and cultural character of Delaware's small coastal and bay towns may be significantly affected.

Potential Environmental Impact: The potential environmental impacts associated with residential properties and structures exposed to sea level rise include: introduction of contaminants from increased flooding and inundation of developed properties; coastal debris from the abandonment or loss of structures; pollution from residential septic systems and the inundation of community wastewater systems; and the loss of shoreline and wildlife habitat and the general reduction in habitat quality of the developed land that is inundated.

#### Future Development Areas

The Delaware Population Consortium projects that by the year 2040, Delaware will be home to 1,120,523 residents — an increase of over 225,000 persons. These projections are routinely used by State, County and municipal governments to plan how and where future residential and commercial development will occur (Delaware Population Consortium, 2010).

Delaware encourages proactive planning for the state's future growth needs through a variety of mechanisms, including the Strategies for State Policy and Spending, implemented by the Office of State Planning Coordination. These strategies set forth guidelines and maps for where the state plans to make investments of public funds for roads, sewer, schools, and other infrastructure. It also outlines those areas where the state will direct funding for investments in agriculture and natural resource preservation. The strategies incorporate the zoning and future land use desires of county and municipal governments as outlined in their comprehensive development plans. The Strategies were first approved in 1999 and were updated in 2004 and 2010. Executive Order 26 states that "All state departments and agencies shall use the Strategies document and maps as a guide to making all decisions on policy, infrastructure and other investments, and resource management."

Inundation as a result of sea level rise could affect the availability and suitability of designated future growth areas for development. This could, in turn, drive the need for changes to development patterns in areas not subject to inundation from sea level rise to accommodate necessary growth.

Exposure to Sea Level Rise: Level 3 development areas, as designated by the Strategies for State Policy and Spending, were used to determine exposure of future growth areas to sea level rise. Level 3 areas are lands within the long-term growth plans (greater than five years) of county and municipal governments and/or are adjacent to already developed or developing areas. Some of these planned growth areas will be exposed to sea level rise under the three planning scenarios (See Table 33) and may be unsuitable for development to meet future growth needs.

Statewide, between 3% - 7% of Level 3 land is within an area that could be inundated by sea level rise. In New Castle County, these areas are generally in the areas surrounding the towns of New Castle, Delaware City and Port Penn as well as areas along the Christina River near the 1-95 corridor. In Kent County, these areas are generally growth areas designated by coastal towns like Bowers Beach, Leipsic, and Little Creek for future growth. Fringes of land designated as Level 3 adjacent to the St. Jones River, Murderkill River and Mispillion River in Kent County are also exposed to future sea level rise under these scenarios (See maps in the Mapping Appendix).

In Sussex County, approximately 7 % of level 3 areas within the county would be inundated under the 1 meter sea level rise scenario. The coastal development patterns in Sussex County starkly contrast with Kent County's development patterns in large part because of the resort nature of coastal Sussex County. To meet the demand for homes and services near the Allantic Coast and Inland Bays, future growth areas surround existing development around the Inland Bays. Many of these areas, particularly Angola Neck, Long Neck, and Ferwick along Route 54 will be exposed to future sea level rise. In addition, future growth zones in and around Rehoboth Beach, Lewes and Slaughter Beach will also be exposed.

Table 33 - State Strategy Level 3 Areas Inundated by Sea Level Rise

County	Total Acres of	Total Acres of Land Inundated			Percent of Total Inundated		
	Level 3 Land	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	152,001	3,907	7,777	11,178	3%	5%	7%
New Castle	43,480	428	783	1,107	1%	2%	3%
Kent	25,487	566	815	1,059	2%	3%	4%
Sussex	83,034	2.912	6.178	9.012	4%	7%	11%

Source: Delaware Office of State Planning Coordination, Investment Levels, Delaware State Strategies for State Policies and Spending (2010), 2010-10-01

Potential Economic Impact: Inundation of land within future growth zones could result in a reduction in potential tax base generated by new commercial and residential properties. In addition, development within future growth zones that have the potential to be inundated by sea level rise may be limited by the willingness of purchasers to assume risk, and it may be made more expensive if local communities enact stricter zoning or building codes.

New development in areas that may be exposed to sea level rise may create the expectation that government assistance for infrastructure improvements, flood control and/or buy-outs will be made available if necessary. The cost of these actions could have significant future cost to government entities. A recent report that assessed and proposed solutions for flooding problems in Bowers Beach estimated a total cost of over \$469,000 (KCI Technologies, 2011) for implementation of these solutions. This cost does not include the larger cost of state-provided sand for Bowers Beach for the past 50 years, a protective strategy necessitated by shoreline erosion and long term relative sea level rise, nor does it include costs for flood mitigation at an increased sea level.

It is important to note that costs to individuals and government entities from flood mitigation projects and relocation or elevation of structures conducted as a response to sea level rise will vary depending on individual response to the rising tides. Many people residing or doing business within an inundation zone will accept a certain amount of risk and inconvenience and some may choose to relocate or raise their structures before inundation becomes problematic.

Potential Social Impact: Small coastal towns along the Delaware Bay like Bowers Beach, Leipsic, and Slaughter Beach may choose to limit the extent of their future growth areas, or change the location of their future growth areas based upon these sea level rise scenarios. If unable to find suitable areas to direct their growth, existing commercial and residential areas could fail to meet the needs of nearby residents.

Loss of land due to inundation without adequate planning or nearby land to rebuild could result in abandonment of properties within Delaware's small coastal towns and a reduction in the quality of life within them. In addition, the inundation scenarios indicate that both existing development and future development zones around Delaware's Inland Bays could be significantly affected by sea level rise. Quality of life in and around the Inland Bays may be reduced as a result, but it is important to note that the timeline for anticipated impacts is long and may allow adequate time for adjustments in development areas.

Potential Environmental Impact: Environmental impacts will vary depending upon how land use planners and developers choose to respond, and whether development is discouraged (whether by government action or personal risk tolerance) within potential future inundation zones. Development within these zones could result in a reduced opportunity for land preservation that would allow for tidal marshes to naturally migrate landward and could necessitate the hardening of natural shorelines, among others.

#### Agriculture

Agriculture is a major component of the economic and social backbone of Delaware. The total economic contribution of the agriculture industry to the state is \$7.95 billion per year, supporting about 30,000 jobs. The overwhelming majority of the market sales are poultry (77,3%), followed by corn (6.3%), soybeans (2.9%), and milk and other dairy products (2.0%) (Awokuse, Ilvento, & Johnston, 2010).

According to the United States Department of Agriculture (2012), in 2007, 40% of the land mass in Delaware was classified as agricultural; many of these farms are located in coastal areas. Sea level rise can impact farming operations through permanent inundation of agricultural land, but it can also lead to sall contamination of soil from temporary flooding impacts during storms. Conversations with farmers at public meetings held in November, 2011 indicate that these impacts are already being seen in coastal agricultural areas. In addition, sea level rise can lead to saltwater intrusion into groundwater resources, contaminating irrigation wells with salt water unsuitable for irrigation of crops.

Exposure to Sea Level Rise: Exposure of the agriculture industry and community to sea level rise was assessed by using the State's Land Use/Land Cover maps. These maps outline areas that are used for specific types of land use, classified from aerial photographs. These maps were analyzed with respect to the sea level rise inundation areas to provide a gross indication of the extent and location of potential agricultural impacts.

Statewide, 1% - 4% of the 47,000 acres of mapped agricultural land is within areas that could be inundated by sea level rise (Table 34). Potential for the most concentrated impacts is in a region from southern New Castle County to Lewes, with coastal areas of northern Sussex seeing the most significant potential for concentrated impacts (see maps in the Mapping Appendix). While less than 5% of agricultural land could be potentially inundated from sea level rise, saltwater intrusion may present problems to a larger region; additional studies on saltwater intrusion are necessary before potential impacts can be characterized. It is also important to note that many of the farms within the sea level rise areas are also enrolled in agricultural conservation programs (additional discussion of these areas can be found in the natural resources section of this document).

Table 34 - Acres of Actively Farmed Land Exposed to Sea Level Rise

County	Total Acres of	Total Acres Inundated			Percent of Total Inundated			
	Farmed Land	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State		4,910	10,935	17,199	1%	2%	4%	
New Castle	63,729	834	1,812	2,759	1%	3%	4%	
Kent	166,506	1.248	3,747	6,511	1%	2%	4%	
Sussex	243,562	2,828	5,376	7,928	1%	2%	3%	

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

To understand potential impacts to farm structures, the Land Use/Land Cover maps were also analyzed with respect to the sea level rise scenarios to determine acreage and location of confined animal feeding facilities and farm buildings (Table 35 and Table 36). In general, less than 1% of Delaware's confined animal feeding operations are within areas that could be inundated by sea level rise. Up to 2% of farmsteads and related buildings could be inundated by sea level rise. The largest impact to farmsteads would be in Sussex County where 2% could be inundated at both the 1.0 meter and 1.5 meter scenarios. Due to the nature of the Land Use/Land Cover maps and the way in which structures are classified, the acreages reported in these tables are likely overestimated.

Table 35 - Acres of Confined Animal Feeding Operations Exposed to Sea Level Rise

	Total Acres	Total	Acres Inund	ated	Percent of Total Inundated		
County	of Confined Feeding Operations	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	9,672	6	24	74	<1%	<1%	1%
New Castle	156	0	1	1	0%	<1%	<1%
Kent	1,554	1	4	11	<1%	<1%	1%
Sussex	7,964	5	20	62	<1%	<1%	1%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

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Table 36 - Acres of Farmsteads and Related Buildings Exposed to Sea Level Rise

	Total Acres of	Total Acres Inundated			Percent of Total Inundated			
County	Farmsteads and Related Buildings	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	14,060	54	149	238	<1%	1%	2%	
New Castle	2,781	6	23	36	<1%	<1%	1%	
Kent	5,389	13	34	66	<1%	1%	1%	
Sussex	5,890	35	92	136	1%	2%	2%	

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008 05 19

Potential Economic Impact: The loss of productive agricultural land to inundation and salt contamination decreases the profitability of individual farms and may make it increasingly difficult for family farmers to stay in business. It could also reduce the number of employment opportunities in the agricultural sector. The loss of local corn and soybean crops could also affect local feed sources and costs for the poultry industry. Landowners wishing to protect tillable acreage may also bear costs of shoreline protection strategies.

Specific studies to determine the economic impact of sea level rise to the agricultural industry are outside the scope of this assessment, but the workgroup acknowledges the importance of collecting this information.

Potential Social Impact: The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to move outside of the inundation zone, causing losses to the local agricultural heritage of a community. Delaware takes pride in having locally grown food sources; these sources have the potential to become lost as prime farmland becomes inundated with rising sea levels.

While the social impact may be significant in small geographic areas, the statewide exposure of agricultural acreage ranges from only 1-4% of the total agricultural area in the state. Based on this small statewide exposure, the farming community in Delaware is likely to be resilient to these changes.

Potential Environmental Impact. Agriculture in Delaware often relies on irrigation; groundwater withdrawals in coastal areas, combined with sea level rise, may increase saltwater intrusion into groundwater or aquifers and affect adjoining properties. Additional information about groundwater intrusion is available in the Natural Resources section of this document.

Inundation of agricultural land may also result in decreased areas for wildlife to forage or rest. Migratory geese in particular, utilize farm fields heavily during their winter stopover in Delaware.

As with residential and commercial areas, there is potential for loss of vegetated shorelines and their associated habitat, if landowners choose to protect the shoreline with rock or bulkheads to reduce flooding.

### Tourism and Coastal Recreation

Tourism is a critical part of the economy for the state of Delaware; tax-free shopping, family-friendly beaches, excellent restaurants, sporting events, and slot machines all draw non-Delawareans into the state to recreate and spend money. In 2010, the last year for which tourism data is available, 7.1 million people visited Delaware, generating \$400 million in state and local government taxes and fees and 39,000 jobs. Of those visiting Delaware from outside of the state, 24% dined in Delaware, 25% came here to shop, 16% to gamble, and 19% for beach activities (DEDO, 2012).

Coastal recreation opportunities in Delaware are a large component of the tourism industry, as well as a way of life for Delaware residents. A 2006 national survey of wildlife recreation found that 395,000 people who live in or visited Delaware fished, hunted, or watched wildlife in the state. Of the total number, 159,000 people fished, 30,000 people hunted and 285,000 participated in wildlife-watching activities, which includes observing, feeding, and photographing wildlife. During this time, state residents and nonresidents spent \$299 million on wildlife recreation in Delaware. Of that total, trip-related expenditures were \$75 million and equipment purchases totaled \$204 million. The remaining \$20 million was spent oil icenses, contributions, land ownership and leasing, and other items (U.S. Department of the Interior, 2006).

Sea level rise will bring changes to many of the places and amenities that people visit and enjoy in Delaware. Waterfront restaurants and retail shops could experience increased frequency of flooding and eventual inundation. Scenic coastal routes like Delaware Route 9 may become difficult to travel on as a result of inundation or ground saturation may damage its structural integrity. Parks, natural areas and beaches may lose ground to inundation and erosional forces, and wildlife populations may relocate or shrink as a result of changing habitats. All of these changes may impact the tourism industry and recreational opportunities in the first state.

Exposure to Sea Level Rise: To assess the potential impact of sea level rise to tourist attractions in the state, the Society and Economy Workgroup attempted to obtain data that contained the locations of tourist attractions, including restaurants, shopping destinations, and hotels, and associated economic data. However, this data is not currently available statewide; therefore impacts to specific tourist attractions and tourist amenities could not be conducted. An analysis of impacts to the business sector in the state (inclusive of hotels and shops) was conducted as part of the statewide vulnerability assessment; those results are available in the Business chapter in this section.

Since gambling is a large component of tourism revenues in the state, the sea level rise scenario maps were compared to the locations of existing gambling sites; none of the three existing gambling sites are exposed to future sea level rise under the three planning scenarios.

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Delaware's State Parks provide visitors with many recreational and educational opportunities, from playing in the waves on the Atlantic Ocean to ghost tours at Fort Delaware. To assess potential impacts to these recreational opportunities, park boundary information was obtained from Delaware's Division of Parks and Recreation and used to determine the number and percentage of acres of parks within each of the three sea level rise planning scenarios (Table 37). Statewide, 25% of State Park land is within an area that could be inundated by sea level rise of 0.5 meters, up to 35% of State Park land is within areas that could be inundated by sea level rise of 1.5 meters. Potential inundation is most significant along the Atlantic Coast and Inland Bays in Sussex County: however, parks along the Delaware River in New Castle County could also be significantly affected. The Mapping Appendix indicates the state parks that could experience inundation, and provides a piegraph indicating the extent of potential inundation at each scenario.

Additional resources that could impact outdoor recreational opportunities are discussed in the Natural Resources Section of this document.

Table 37 - Acres of Delaware State Parks Exposed to Sea Level Rise

	Total Acres	Total Acres Inundated			Percent of Total Inundated		
County	Iotal Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	25,164	6,348	7,865	8,865	25%	31%	35%
New Castle	8,766	279	450	550	3%	5%	6%
Kent	1,601	0	0	0	0%	0%	0%
Sussex	14,796	6,069	7,415	8,316	41%	50%	56%

Source: Delaware Division of Parks and Recreation, 2011

Potential Economic Impact: Because many coastal resort areas contain land or amenities that could be inundated in the future and because many of the natural places that visitors seek out will experience inundation or habitat changes, alterations to tourism patterns could be expected as a result of sea level rise. If these patterns lead to decreased numbers of visits or decreased spending by visitors, tourism revenue will decrease, impacting business owners, employees of coastal businesses and tax revenues. However, should sea level rise result in entrepreneurial opportunities and expansion of amenities, tourism revenues may increase. For example, deeper water could allow some rivers, harbors, or marinas to accommodate boats with deeper DRAFTs, and could reduce the need for maintenance dredging of accommulated sediments.

In addition to changes in tourism revenue, sea level rise is expected to increase the costs of maintaining amenities and tourist destinations. For example, as sea level rises and flooding becomes more frequent, business owners may need to flood-proof or raise their buildings, parking tots, and docks. The cost to maintain sandy beaches may also increase. Delaware routinely partners with federal and local partners to replenish (or add sand to) its publically accessible Atlantic Ocean and Delaware Bay beaches, a strategy that has ensured that visitors and residents have space to enjoy a day at the beach while simultaneously protecting buildings, infrastructure and natural resources behind the dune from storm damage. Boardwalks, trails and viewing platforms that provide eco-tourism opportunities throughout the state may also require additional funding for maintenance or relocation to remain available and useful.

Potential Social Impact. The social fabric of many of Delaware's small coastal towns is based around fishing, boating, beach access, and the tourism that those activities bring. Reductions in the availability of these amenities as a result of sea level rise may affect tourism levels and local business revenues, leading to loss of business services and sense of community.

Potential Environmental Impact: Tourism and outdoor recreation contributes directly to environmental stewardship and natural resource conservation in the state of Delaware through financial contributions to restoration and through increased environmental awareness.

For example, one percent of the state's accommodation tax goes directly into the Beach Preservation Program of the Department of Natural Resources and Environmental Control, where it is used to help meet federal match requirements for beach replenishment projects. A reduction in the number of hotels and hotel guests could reduce this revenue stream, and thus the ability of the State to have the financial resources to conduct beach replenishment projects. However, seasonal rental homes are currently exempt from the accommodation tax; had seasonal home rental spending been subject to the tax, and addition \$72 million in state revenue would have been generated in one year (DEDO, 2012).

Similarly, many of the state's wildlife conservation programs are supported by a federal excise tax on hunting equipment and ammunition and by the Federal Duck Stamp, which migratory waterfowl hunters must purchase each year. Losses or changes to important wildlife habitat could reduce the number of hunting opportunities, and thus reduce the revenue stream for conservation programs.

### Historic and Cultural Resources

Historic resources are the physical places that embody Delaware's past, contain important information about the lives and history of our ancestors, and preserve the past for Delaware's future generations. Historic resources include buildings, structures, archaeological sites, landscapes, objects, and historic districts (areas with multiple numbers of individual resources) generally built before 1961. Historic resources can be found on land, in the water, and submerged on subaqueous lands.

Most historical resources are in private ownership. The public though, can enjoy the historic landscape around them as they drive, particularly on Delaware's Scenic and Historic Byways, and when they visit Delaware's historic towns, such as New Castle and Lewes, both of which have large historic districts. In addition, historians and researchers use and interpret these resources. Various historic museums are run by the state, as well as a number of private non-profits around the state, that provide historic interpretations and educational experiences for the public and for students at all grade levels. State parks also include many historic resources, for instance, the Fort Miles Historic District at Cape Henlopen State Park, and provide educational and recreational experiences for the public.

Sea level rise can affect historic and cultural resources in several ways. Damage to buried archaeological resources begins with a rise in the water table, leading to leaching of chemical and organic contents of the site. This results in loss of the information potential of the site to archeologists and historians. Inundation can cause structural damage or loss of historic buildings, historic vistas, and artifacts.

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### Exposure to Sea Level Rise

The Delaware State Division of Cultural and Historic Affairs' State Historic Preservation Office maintains a database of known historic and cultural sites in Delaware (State Historic Sites) and a database of National Historic Register Sites. The sea level rise scenario areas were overlaid with this database to determine the number and location of historic resources that are within areas potentially inundated by sea level rise. The Division of Cultural and Historic Affairs continually updates these databases, but not all areas in Delaware have been surveyed for historic resources and errors do exist in their data.

Table 38 and Table 39 below indicate the number of State Historic Sites and National Register Sites that could be inundated by sea level rise. Because of incomplete mapping, the summaries in the analysis table are likely an underrepresentation of the potential exposure of historic resources to sea level rise.

Between 2% - 4% of the 14,316 known historic sites in the state of Delaware are within areas that could be inundated by sea level rise. Between 2% - 5% of the state's 640 National Historic Register sites are within areas that could be inundated by sea level rise. Geographically, potentially impacted historic resources are widespread throughout the state (Map in the Mapping Appendix). Note that the maps show no impacts in northern and western Sussex Country; this is due to lack of historic data collection in these areas and not necessarily because no historic resources exist in these areas.

Table 38 - Number of State Historic Sites Exposed to Sea Level Rise

County	Total Number of State	Total Number of Historic Sites Inundated					
	Historic Sites	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	14,316	244	441	634	2%	3%	4%
New Castle	6,645	79	137	181	1%	2%	3%
Kent	5,429	113	206	298	2%	4%	5%
Sussex	2,242	52	98	155	2%	4%	7%

Source: Delaware State Historic Preservation Office, CRS Inventory, 2011, unpublished.

Table 39 - Number of National Register Sites Exposed to Sea Level Rise

Total Number County of National Register Sites		Total Number of National Register Sites Inundated			tuniber					
	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m				
State	640	14	24	32	2%	4%	5%			
New Castle	380	4	6	9	1%	2%	2%			
Kent	141	5	10	14	4%	7%	10%			
Sussex	119	5	8	9	4%	7%	8%			

Source: Delaware State Historic Preservation Office, National Register of Historic Places for Delaware, 1997-12-01 Potential Economic Impact: Economic impacts of permanent inundation of historic resources include direct loss of buildings, structures, and landscapes as well as the revenues that are generated from them, whether home business, farms, or tourism. In addition, tax revenue to state and local governments could be affected by direct loss of property, although some of these properties may be tax-exempt.

In addition to direct losses, there are significant costs associated with moving historic buildings, structures, and cemeteries, raising historic buildings and structures above flood levels, providing flood protection for historic resources, repairing flood damage to historic resources, and/or conducting data recovery excavations of significant archaeological sites. In certain circumstances, some owners of historic resources may have a legal obligation to relocate or document the resource if loss is imminent, such as in the case of permanent inundation. Indirectly, loss of tidal marshes and other natural communities that provide natural flood mitigation to upland properties may exacerbate inundation impacts to leads historic resources.

Potential Social Impact: While not immediately visible to the public, the loss of archaeological sites means the irrecoverable loss of information that may be significant to understanding Delaware's past, representing a serious loss for researchers, archaeologists, historians, and even environmentalists interested in reconstructing past ecologies. Damage to archaeological sites begins with rises in the water table, leading to leaching of chemical and organic contents of the site, thereby damaging the information potential of the site well before a site is permanently inundated.

Additionally, properly owners could experience loss of their historic homes and commercial properties such as stores and farms. Quality of life for all Delawareans could be impacted because historic resources are a large part of the community character of Delaware's towns as well as the look and feel of its rural areas, creating pleasing view-sheds, walkable neighborhoods, interesting streetscapes, and recreational and cultural opportunities.

Potential Environmental Impact: Some historic buildings may still contain lead-based paints and asbestos and there may be other chemicals and contaminants remaining in historic farms, mills, and industrial sites, Inundation of these sites could release hazardous materials into the water column. In addition, inundation of cemeteries may result in the release of lead and other toxins that are used in burial materials.

### Socially Vulnerable Populations

Socially vulnerable populations are neighborhoods or groups that are less likely to have the resources to respond to environmental threats like sea level rise due to a variety of factors including educational level, economic standing, age, family status, and access to services.

Citizens in areas identified as socially vulnerable may lack the ability or resources to adapt to sea level rise. They may not have the financial resources to flood-proof their homes or relocate if sea level rise begins to affect their neighborhood. They may also lack their own transportation or lose access to transportation should bus routes or bus stops be relocated due to road flooding in the region; this could also affect their ability to travel to and from work. In addition, these communities are often near or within areas of already poor environmental quality and may disproportionally be affected by indirect impacts of sea level rise such as contaminant releases from underground storage tanks or contaminated sites.

Socially vulnerable populations were discussed and considered throughout this document but were not ranked with the other resources analyzed because assessment of these communities will need to be conducted at a more localized scale and with consideration of the interaction of numerous direct and indirect sea level rise impacts. Attention to fair treatment of socially vulnerable communities should be forefront in the minds of decision-makers as plans are made to adapt to the effects of sea level rise. Strategies that are developed for sea level rise should seek to avoid disproportionate effects to socially vulnerable populations as described below.

## Society and Economy

Exposure to Sea Level Rise: To understand the location and extent of populations that could be particularly susceptible to the effects of sea level rise, two social vulnerability indicators were utilized: The Wilmington Planning Area Council's (WILMAPCO) Environmental Justice (EJ) areas and the Social Vulnerability Index (SoVI).

Environmental Justice entails the fair treatment and meaningful involvement of people from all races, cultures, and incomes regarding the development of environmental laws, regulations and policies. An outgrowth of Title VI of the Civil Rights Act of 1964, EJ is a policy to ensure the non-discriminatory distribution of federal funds in the U.S. During his terms, President Clinton issued a pair of Executive Orders (EO) which detailed the EJ responsibilities of federal agencies. EO 12898, signed in 1994, requires agencies to identify and avoid disproportionately high and adverse effects on low-income and minority populations. Six years later, EO 13166 called for outreach and involvement of persons with Limited English Proficiency (LEP). A decade later, President Obama reinvigorated the federal government's commitment to EJ. Strategies across federal agencies were revamped, with weight added to the following areas: public engagement, implementation of the National Environmental Policy Act (NEPA) and Title VI, the relationship of climate change to EJ, and the impacts of freight movement.

EJ areas in Delaware were identified by WILMAPCO for use in transportation planning projects. Using data from the 2000 Census, block groups were given points based on the percentage of low-income, black, Hispanic, and Asian persons. Based upon the number of points, block groups were scored as either having a Low, Moderate or Significant concentration of at-risk residents (WILMAPCO, 2009).

A Social Vulnerability Index is a quantitative measure of social vulnerability to environmental hazards. Social vulnerability focuses on demographic and socioeconomic factors that increase or attenuate the impact of environmental hazards (like sea level rise) on local populations. The Social Vulnerability index (Cutter, Bryan, & Shirley, 2003) uses a similar strategy to identify block groups that are particularly susceptible to environmental hazards, but uses 32 variables to score each block group. These variables include race and income like the WILMAPCO method, but also includes percentage of elderly residents, percent female headed households, hospitals per capita, housing values, percent employment, education level, and others. Vulnerable block groups are identified as those whose scores are greater than one standard deviation above the mean (Cutter, Bryan, & Shirley, 2003). SOVI data at a block group level was obtained from the National Oceanic and Atmospheric Administration for use in this assessment.

Due to recent changes in the way in which demographic data is collected through the US Census, the most robust and useable dataset for social vulnerability analysis is the 2000 Census. This analysis should be updated as new demographic data is available.

Using these two methods, block groups whose boundaries were within any sea level rise scenario were identified; these block groups were further analyzed to determine if there were any residences that would be exposed to sea level rise. Block groups with at least one affected residence were included in the results below. It is important to note that in many cases, only a small sliver of each block group is exposed to sea level rise, and the remainder of the block group is outside of the area of concern. Additional analysis will be necessary to discern the social vulnerability within affected parcels.

Results of the two different techniques for identifying at-risk populations varied widely, likely as a result of the increased number of variables used by the SoVI versus the WILMACPO method. The SoVI, likely due to its inclusion of age and infrastructure factors, identified more rural and resort areas as vulnerable, but also included areas of dense development in Wilmington, Dover, and Milford. The Environmental Justice Areas, because of the focus on race and income, was more likely to identify urban areas in Wilmington, Milford, Dover, and Seaford. However, smaller towns and rural areas were also identified as vulnerable.

Block groups identified as environmental justice areas or socially vulnerable areas by this analysis are listed below. Block groups in italics indicate that the block group was identified by both methods.

#### WILMAPCO Environmental Justice Areas - Significant

- North of Wilmington, east of 13 (Tract 101700, Block Group 4)
- South Wilmington, East of Christina River and West of Heald Street (Tract 1900, Block Group 2)
- Milford, North of Mispillion River and west of 113 (Tract 042500, Block Group 2)

#### WILMAPCO Environmental Justice Areas - Moderate

- Wilmington, North of Brandywine River (Tract 000700 Block Group 2, Tract 000602 Block Group 2 & 3)
- City of Wilmington, northwest of Christina River (Tract 002700, Block Group 1)
- City of Wilmington, north of Christina River (Tract 002000, Block Group 1)
- North of Delaware City (Tract 0163303, Block Group 1)
- · Bear, west of 7 (Tract 014902, Block Group 1)
- Southeast of Middletown (Tract 016802, Block Group 1)
- Eastern Kent County (Tract 040400, Block Group 1)
- East of Dover (Tract 041000, Block Group 1)
- Downtown Dover, along the upper St. Jones River and Silver Lake (Tract 040900, Block group 1)
- West Milford (Tract 050102, Block Group 3)
- Milton and vicinity (Tract 050801, Block Group 2)
- Seaford, North of Nanticoke River (Tract 050402, Block Group 2)
- Laurel and South of Laurel (Tract 051802, Block Group 2)

#### Social Vulnerability Index - High Vulnerability

- East of Christiana River (Tract 012900, Block group 2)
- Downtown Dover, along the upper St. Jones River and Silver Lake (Tract 040900, Block group 1)
- Lewes along the L&R Canal (Tract 050900, Block Group 3)
- Seaford, North of Nanticoke River (Tract 050402, Block Group 2)
- Millsboro, along Indian River (Tract 050602, Block Group 1)
- Sussex County along north side of Indian River (Tract 050702, Block Group 1)

#### Social Vulnerability Index - Moderate Vulnerability

- City of Wilmington, northwest of Christina River (Tract 002700, Block Group 1)
- West of Route 13 in Smyrna and Kent County (Tract 040203, Block Group 2)
- Milford west of Route 113 (Tract 042500 Block Group 2, Tract 050102, Block Group 1)
- Milton and vicinity (Tract 050801, Block Group 2)
- East of Millsboro, north side of Indian River (Tract 050702, Block Group 2)
- East and South of Dagsboro, including Frankford (Tract 051500, Block Group 2)
- East of Selbyville (Tract 051302, Block Group 1)

## Society and Economy

These results should be considered as a screening upon which to base additional investigations into the potential impact that sea lavel rise may have on communities. Americans have proven to be highly economically mobile throughout their lifetimes, and community composition is likely to change over our 88 year planning horizon. In addition, these methods identified some block groups as vulnerable based upon age and fixed incomes; these individuals may actually have sizeable assets and wealth to use as resources to adapt.

Potential Economic Impact: The potential economic impacts associated with exposure of socially vulnerable populations to sea level rise include costs associated with home maintenance, employment opportunities, and social services. Although it can be assumed that many socially vulnerable individuals rent their homes; flooding of residences may result in increased or unplanned costs for home repair or relocation. For homeowners, this may result in increased insurance costs or repairs after flood events. There could also be unanticipated costs for renters as well; including relocation costs (first and last month's rent, security deposits etc.) should this become necessary due to safety or structural issues. Alternate housing options may also be limited for those using subsidized housing programs.

In some neighborhoods, flooding of buildings could also result in loss of employment within the vicinity; those residents who do not have a car may lose employment opportunities within walking distance and may have difficulty with the costs associated with traveling by car. In addition, the nature of social services needed for residents of these areas may evolve in the future, requiring more government resources to help them respond, recover, or adapt to sea level rise.

Potential Social Impact: The potential social impact associated with the exposure of socially vulnerable populations to sea level rise includes the loss of housing, of 'local' identity, loss community structure, and character, loss of employment opportunities, and the loss of a social network. In many small communities, neighbors support neighbors through emergency babysitting, rides to work, and block watches, Any action that would result in the relocation of families could have an isolating affect, particularly in multi-generational communities or communities with long tenure. Increased flooding and structural damages will also impact quantity and quality of social service resources needed and available for these populations.

Potential Environmental Impact: The potential environmental impacts associated with the exposure of socially vulnerable populations to sea level rise include exposure to contaminants, water quality and health effects. Some socially vulnerable communities are located near industrial sites and brownfields (formerly industrial sites suspected of having contamination). Inundation of these sites may release contaminants (mercury, arsenic, PCBs etc.) into the water column, increasing the likelihood of these contaminants coming into contact with humans through a variety of means.

Sea level rise may also affect the function and safety of septic systems and drinking water wells; persons and communities unable to bear the costs of repair or replacement will be particularly affected. Increased water tables or inundation could cause septic systems to no longer drain properly or to back up into homes; this exposes humans and the water supply to bacteria, pathogens, and other pollutants. Increased water tables and inundation could also cause well-water to become safty affecting the quality and quantity of drinking water supplies.

Sea level rise may also increase the number of people at risk for health conditions related to standing water, wet building materials, and sustained high indoor humidity. Standing water can result in increased mosquito populations and exposure to mosquito borne disease. Wet or damp basements and high indoor humidity can result in increased mold spores and increased incidences of asthma and allergies.



Public Safety and Infrastructure

The Public Safety and Infrastructure Workgroup was formed to collaboratively investigate the potential effects of sea level rise on the public safety, transportation, utility, service, and industrial infrastructure of Delaware. Its results are presented below and in the following sections. The effects of sea level rise on infrastructure is relatively straight-forward; with facilities exposed to sea level rise subject to damage or reduced usefulness. When the economic, environmental, and social impacts are taken into consideration the issue becomes more complex and interrelated; the workgroup recognizes that the information that has been gathered and presented through this vulnerability assessment process is not complete in many cases; much more research will need to be conducted to answer many of the questions posed by the workgroup in its discussions.

#### Assessing Exposure of Public Safety & Infrastructure Resources

The Public Safety and Infrastructure Workgroup was composed of members of the Sea Level Rise Advisory Committee, additional subject matter experts, and members of the public. A list of those who participated in this workgroup is available in Appendix C. The workgroup met five times between February 2011 and March 2012 to identify, assess, and rank issues related to sea level rise, public safety, and infrastructure.

#### Resources Considered

Specific resources that the Public Safety and Infrastructure Workgroup was initially concerned with but which were not included in the assessment due to a lack of information or impact include the following:

#### Lack of Information:

- · Emergency shelters
- DelDOT maintenance yards
- Electric generation stations
- Electric distribution stations
- Telephone switching stations
- Electricity and communication utilities
- Governmental buildings
- Water lines
- Sewer lines

### No Impact:

- Correction facilities
   Airports
- Hospitals
- 911 call centers
- Public schools
- Cell towers

After discussion , initial data collection, and analysis by Delaware Coastal Program staff, the workgroup narrowed their focus to the following topics: dams, dikes & levees; emergency service facilities; evacuation routes; DART bus routes & stops; navigation aids; The Port of Wilmington; railroad lines; public boat ramps & piers; roads & bridges; septic tanks & disposal fields; underground pipeline utilities; wastewater facilities; wells; adult & child care facilities; cemeteries; public and private schools; brownfields; landfills & salvage yards; DNREC SIRS contaminated sites; and underground storage tanks.

#### Assessing Exposure

As described in the Introduction section, Delaware Coastal Programs staff worked with workgroup and committee members to collect data and information about each resource that the workgroup wished to assess. Based upon available data, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. When possible, regional studies on sea level rise, such as WILMAPCO's Transportation Vulnerability Assessment of the Wilmington, Delaware Region, were used to compare and contrast results (WILMAPCO, 2011).

All of this information was compiled together into a comprehensive assessment for each resource, which was reviewed and edited by workgroup members. Full text of each one of these assessments follows.

### Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a statewide level screening of resources at risk to sea level rise. In many cases, the data that was provided showed the impact to the physical structure but was unable to fully convey the economic, social, and environmental ramifications of sea level rise on a given resource. For example, wastewater facility data showed the number of facilities that are exposed to sea level rise but did not detail the number of residents that would be affected if these structures lost functionality. Damilevee data also ran into this issue with only the physical structure being analyzed. Data overlap was another issue for the Public Safety and Infrastructure workgroup. Some resources, such as brownfields and salvage yards, were subsets of other resources like SIRS contaminated sites. These overlaps lead to the development of multiple exposure assessments for a similar resource. However, these data issues do not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts.

#### Assessing Vulnerability of Public Safety & Infrastructure Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Public Safety and Infrastructure Workgroup conducted an exercise to assess the vulnerability of the state to the effects of sea level rise for each resource. Using standardized questions, the workgroup considered the two primary factors: the geographic scope of impacts and whether the resource could continue to "function". For geographic scope, the workgroup considered both the discrete locations of the impacts themselves and the extent to which impacts may be felt outside these locations. For example, although the exposure of wells is concentrated along the coast, the effects of exposure could be felt statewide due to an increase in demand pressure on inland wells. For "function," the committee considered the extent to which a resource could continue to meet its intended purpose, whether that purpose is to provide emergency services, wastewater treatment, or public services. As a result of this discussion, each resource was ranked as a High Concern, Moderate Concern, Low Concern, or Minimal Concern. Resources ranked as high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

#### High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: Darns, Dikes and Levees, Port of Wilmington, Railroad Lines, Roads and Bridges, Wells, and Evacuation Routes. A high concern resource is generally a resource where inundation of a resource would cause it to no longer function and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruption of services. Additional research and development of adaptation strategies for high concern resources is recommended.

Dams, Dikes & Levees: Between 39% and 78% of the state's 50 miles of dams, dikes and levees could be inundated by sea level rise by 2100. The highest concentration of potential impact is focused in Kent County, whose dikes primarily protect wildlife areas. The majority of the dikes in New Castle County protect people, property, and, in one case, a contaminated site. These structures were built to provide a certain level of containment or protection. If a breach or structural failure were to occur, the resultant flooding could affect a large area inland of the structure. Due to these considerations, inundation of dams, dikes, and levees in the state was ranked as a high concern.

Port of Wilmington: Between 36% and 73% of the Port of Wilmington's property is within an area that could be inundated by sea level rise by 2100. The port is based in northern New Castle County; however, the economic value to Delaware and the entire Northeast Region makes exposure to sea level rise a state and regional issue. Due to these considerations, inundation of the Port of Wilmington was ranked as a high concern.

Railroad Lines: Between 2% and 6% of the state's railroad lines are within an area that could be inundated by sea level rise by 2100. The highest concentration of impact is focused in New Castle County. Even with smaller amounts of exposure in Kent and Sussex Counties, it should be noted that if a single rail line segment becomes inundated, the entire functionality of the line could be lost. This may impact industries served by rail such as power plants and the Delaware City refinery. Passenger travel is also a concern; disruptions and possible restrictions to the Amtrak rail line could impact travel throughout the northeast corridor. Because disruption of rail service in Delaware could have impacts throughout the state and region, inundation of railroad lines as a result of sea level rise was ranked as a high concern.

Roads & Bridges: Between 1% and 5% of the state's roads and bridges are within an area that could be inundated by sea level rise by 2100. Inundation of an individual segment of road could cause regional transportation disruptions, particularly if no alternative routes are available. The highest concentration of roadway exposure to sea level rise was found in Sussex County; however, potential exposure was found throughout the state. Due to the potential regional impacts, inundation of roads and bridges from sea level rise was ranked as a high concern.

Wells: Residents and businesses in Kent and Sussex Counties rely on groundwater resources for drinking, irrigation and industrial purposes. Operation of wells that extract groundwater can be compromised by inundation from sea level rise, and the quality of groundwater can be compromised by saltwater intrusion resulting from sea level rise. Statewide, between 3% and 7% of domestic wells, 3% and 7% of industrial wells, 1% and 2% of irrigation wells, and 2% and 10% of public wells are within an area that could be inundated by sea level rise by 2100. Potential exposure of wells to sea level rise is focused along the coast; however, reduction in availability of groundwater in the coastal areas may increase demand on inland public wells. Because access to clean water is a necessity and because demand on inland wells may increase, sea level rise impacts to wells was ranked as a high concern.

Evacuation Routes. Between 1% and 6% of the state's evacuation routes are within an area that could be inundated by sea level rise by 2100. Interstates and arterial roads tend to serve as the major evacuation routes for emergencies; substantial reliance on a single mode of transportation for evacuations may endanger many people if the highway infrastructure is made inaccessible because of sea level rise. All three counties experience exposure but the highest concentration is found in Sussex County. Because evacuations rely on automobile transportation and because flooded roadways can prevent or slow evacuation by car, inundation of evacuation routes was ranked as a high concern.

#### Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup the following resources are of moderate concern: Septic Systems and Disposal fields, Landfills, and Wastewater Facilities. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impacts is less than statewide.

Septic Systems & Disposal Fields: Statewide, between 1% and 4% of septic systems are within an area that could be inundated by sea level rise by 2100. The highest concentration was found in Sussex County, with a focus around the Inland Bays. Functionality issues may arise well before inundation due to rising water tables. This may result in the potential for significant environmental and public health issues related to groundwater contamination. Since potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to septic systems were ranked as a moderate concern.

Landfills: Sites included for this resource range from large state permitted landfills operated by major companies such as NRG, Waste Management, and Delaware Solid Waste Authority to small privately or municipally owned sites, some of which are no longer in operation. Between 1% and 3% of landfill acreage is within an area that could be inundated by sea level rise by 2100. It should be noted that state permitted landfills are expected to see little to no direct exposure to inundation. While the impact to the resource is relatively small and the scale is localized with a focus in northern New Castle County, landfill disruption is still considered to be a statewide concern. These sites service a large area and the need for future rezoning may be an issue. The possibility of contamination migration was another factor considered when determining risk. Due to these considerations, inundation of landfills was ranked as a moderate concern.

Wastewater Facilities. Sites included for this resource included sewer pumping stations, spray irrigation fields, and public treatment/collection facilities. Statewide, between 7% and 21% of sewer pumping stations, 0% and 17% of spray irrigation fields, and 0% and 13% of public treatment/collection facilities are within an area that could be inundated by sea level rise by 2100. The majority of the exposure will be focused in eastern Sussex County; however, New Castle and Kent Counties have wastewater facilities that are also affected but to a lesser extent. These facilities service a large number of people so the potential impacts will be much larger than the percentages indicate. In some cases, impacts may be experienced before inundation occurs due to rising water tables. Taking all available information into account, inundation of wastewater facilities was ranked as a moderate concern.

#### Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Brownfield Sites, Salvage Yards, Underground Storage Tanks, DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites, and Underground Pipeline Utilities. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts will not be significant and/or isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Brownfields: Between 9% and 25% of brownfield sites throughout the state are within an area that could be inundated by sea level rise by 2100. Geographically, the exposure is focused in the Wilmington area with only one site being located outside of New Castle County. If sites become inundated, the release of contaminants may lead to serious health and environmental complications for the surrounding community; however, some sites have been or are currently being remediated. Due to the limited geographic extent of impacts, the inundation of brownfield sites is of low concern at this time.

Salvage Yards: Between 11% and 26% of salvage yards throughout the state are within an area that could be inundated by sea level rise by 2100. Geographically, the exposure is focused in Northern New Castle County with only 1 site being located in a different county. Salvage yards contain a variety of contaminants; however, many sites are currently in the process of being remediated. Due to these considerations, inundation of salvage yards is of low concern at this time.

Underground Storage Tanks (UST): Between 2% and 6% of UST sites throughout the state are within an area that could be inundated by sea level rise by the year 2100. While sites are exposed in all three counties, the scale appears to be localized in nature with a focus on the Wilmington area and the beach communities. If sites are inundated, the release of contaminants may lead to health and environmental impacts for the surrounding community. Due to the limited geographical extent of impacts, the inundation of UST sites is of low concern at this time.

DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites: Between 41% and 54% of SIRS sites throughout the state are within an area that could be inundated by sea level rise by the year 2100. Geographically, the exposure is focused in the Wilmington area, Bombay Hook, and the beach communities. If these sites become inundated, the release of contaminants may lead to health and environmental complications; however, SIRS sites have already been identified, evaluated, and in many cases, remediation is complete or currently taking place. Due to these considerations, inundation of SIRS contaminated sites is of low concern at this time.

Underground Pipeline Utilities: This resource includes natural gas and petroleum pipelines. Workgroup members also initially considered water and sewer pipelines; however, data was unavailable due to privacy and homeland security concerns. Between 4% and 6% of pipeline utilities throughout the state are within an area that could be inundated by sea level rise by the year 2100. While sections of pipeline are exposed in all three counties, the highest concentration is found in New Castle County. The results from the analysis showed that major supply lines will not be affected; however, distribution along with pipeline corrosion may become issues in the future. Due to these considerations, inundation of underground pipeline utilities is of low concern at this time.

#### Minimal Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Adult and Child Care Facilities, Cemeteries, Schools, Leaking Underground Storage Tanks, DART Bus Routes and Stops, Navigation Aids, Public Boat Ramps and Piers, and Emergency Services. A ranking of minimal concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather the impacts will be minor in nature or isolated to a small geographic region. Minimal concern resources should be re-assessed in subsequent planning activities.

Adult & Child Care Facilities: Between 0% and 1% of adult and child care facilities throughout the state are within an area that could be inundated by sea level rise by the year 2100. Due to the sporadic nature and low number of potentially exposed sites, adult and child care facilities are of minimal concern at this time.

Cemeteries: Between 2% and 4% of cemeteries are within an area that could be inundated by sea level rise by the year 2100. All cemetery sites that are potentially exposed are located in Sussex County. Due to the local nature and small number of impacted sites, cemeteries are of minimal concern at this time.

Schools: This resource includes both private and public schools. Statewide, only one school is within an area that could be inundated by sea level rise by the year 2100. Due to the small number of potentially impacted facilities statewide, sea level rise impacts to schools is of minimal concern at this time.

Leaking Underground Storage Tanks (LUST): Between 1% and 5% of LUST sites are within an area that could be inundated by sea level rise by the year 2100. All three counties have exposed sites with slight concentrations in Wilmington and along the Inland Bays. The geographic scale is localized and many of the sites are still active. These LUST sites are known to be sources of contamination and are currently being remediated. Due to these considerations, inundation of LUST sites is of minimal concern at this time.

DART Bus Routes & Stops: Between 1% and 3% of DART bus routes and stops are within an area that could be inundated by sea level rise by the year 2100. It should be noted that Kent and Sussex Counties do not rely on mass transit the way that New Castle County does. Bus routes and stops constantly shift with demand and there is little to no cost involved with these shifts. Due to these considerations, inundation of DART routes and stops is of minimal concern at this time.

Navigation Aids: Since navigation aids are situated on or near the water, 100% are within an area that could be inundated by sea level rise by the year 2100. Most navigation aids are designed to withstand the effects of sustained wave action meaning the majority of devices will only see minor impacts. Due to these considerations, inundation of navigation aids is of minimal concern at this time.

Public Boat Ramps & Piers: Between 60% and 69% of public boat ramps and piers are within an area that could be inundated by sea level rise by the year 2100. Since ramps and piers are built along the waterfront, impacts from sea level rise should be expected. Impacted ramps and piers are found throughout the state; however, adapting to a higher water level should not be difficult or costly to accomplish. Due to these considerations, inundation of public boat ramps and piers is of minimal concern at this time.

Emergency Services: This resource includes fire and rescues stations, ambulance and paramedic stations, police stations, and emergency operation centers. Statewide, between 0% and 9% of fire and rescue stations, 0% and 3% of ambulance and paramedic stations, 0% and 8% of police stations, and 0% and 14% of emergency operation centers are within an area that could be inundated by sea level rise by the year 2100. All emergency facilities already have a mutual aid backup plan in place. Secondary stations are spread throughout the state and coastal stations routinely move equipment to higher ground in the case of a storm event. This statewide backup network will require little adaptation in the future. Due to these considerations, inundation of emergency services is of minimal concern at this time.

#### Detailed Resource Assessments

The following sub-chapters contain a detailed exposure assessment for each resource and a description of the likely economic, social, and environmental impacts that could result. As discussed in the Introduction section of this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios; not whether the resource will be impacted. For example, a house that has been elevated above the floodplain is counted within the sea level rise inundation area, but that particular house may be unaffected by sea level rise because it has been flood-proofed. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

#### **Public Safety**

### Dams, Dikes & Levees

Dams and levees, also referred to as dikes, are manmade structures constructed of earth or other materials designed to contain or direct water in a river, lake or other water bodies for purposes including, but not limited to, flood control or power generation. Historically, dams in Delaware have been used in the operation of mills for processing agricultural products and irrigation. Likewise, levees in Delaware were initially constructed for agricultural purposes allowing for arable lands, along the Delaware River and Bay, to be farmed. As time passed and development spread, these structures served increasingly as flood control structures, protecting homes and infrastructure placed in flood prone areas.

While these structures provide a certain level of containment or protection and provide great opportunities to Delaware communities, they are not without risk. Levees are continually impacted by wind, waves and tides; natural forces that can gradually erode, and weaken the face of these structures or that can cause significant damage during coastal storm events. High wind and heavy rains can cause wave heights and water levels to increase. Overtopping can result in water moving at a high velocity down an embankment slope which may lead to failure of the structure. Seepage can also result in the instability and failure of these structures. Seepage through a levee or dam may occur when the water level on one face rises, resulting in increased water pressure. This pressure forces water a) through weakened areas of the structure, like those created by animal borrows or cracking from settlement, or b) under the structure as evidenced by boils appearing along the opposing bank. Erosion, overtopping, and seepage are all factors that may lead to collapse and each are

Exposure to Sea Level Rise: Exposure of dams, dikes, and levees to future sea level rise was assessed by using GIS line layers obtained from the Delaware Department of Natural Resources and Environmental Control Dam Safety Program. The layers marked the locations of dams, dikes, and levees throughout the state and were used in to analyze data with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a structure is within an area that is potentially exposed to sea level rise and should not be used to determine if a structure will be able to function. To fully assess the impact sea level rise will have on dams, dikes, and levees, additional criteria will be needed including; construction and materials used; current condition of structure and associated facilities; amount and/ or source of water behind the structure; inventory of infrastructure; population; and other resources protected by the structure.

Statewide, approximately 31 miles of dams, dikes, and levees are within an area that could be inundated by 1 meter of sea level rise, representing 63% of the total miles of the dams, dikes, and levees in the state. Kent County has both the highest number of miles and highest percentage of constructed structures at risk, with between 15% - 88% of its structure being located within a mapped sea level rise area. New Castle and Sussex Counties are both projected to have approximately 7 miles of dams, dikes, and levees exposed at the 1.5 meter scenario. In New Castle County, the majority of the dikes are used to protect communities such as the city of New Castle, whereas dikes in Kent County are primarily wildlife impoundments. See Map Appendix

Table 40 - Miles of Dams & Levees Exposed to Sea level Rise

County	Total Miles	M	iles Inundati	ed	Percent of Total Inundated			
County	rotal wines	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	49.6	19.2	31.4	38.7	39%	63%	78%	
New Castle	10.7	2.4	5.1	7.2	22%	48%	67%	
Kent	27.9	4.1	19.5	24.5	15%	70%	88%	
Sussex	10.9	6.6	6.8	7.0	61%	62%	64%	

Source: DNREC - Dam Safety Program, Dams and Dikes of Delaware, unpublished

Potential Economic Impact: Poorly maintained dams and levees may lead to damage or failure of these structures and the increased risks resulting from sea level rise may put infrastructure, such as homes and businesses protected by these structures, at high risk of flooding and flood damage. The economic impact of structural failure depends on what is being protected. A 2011 study for the city of New Castle was conducted on the four levees that protect the city and surrounding area (Greenstone Engineering, 2011). A cost-benefit analysis for each levee was used to project the results of overtopping or breaching during a 100-year storm event. The water elevation during a 100-year flood event in this area is 8 feet. Damages resulting from this type of event would range from \$8-80 million. The water elevation with 0.5 meter sea level rise in this area is 10.6

Knowing such risks exist could have economic impacts to an area. Insurance companies may raise flood insurance rates for properties protected by inadequate structures. Understanding the risk and potential impacts, business owners may decide to move their operations to a safer location which could mean a loss of tax revenue for local coastal communities.

Potential Social Impact: Limited or changed functionality of dams, dikes, and levees may put a greater percentage of people and property at risk from flooding. As sea levels continue to rise, the threat of overtopping or structural failure could also increase coastal communities' risk of flooding.

Potential Environmental Impact: As with potential economic impacts, the degree of environmental impacts resulting from levee failure depends on what is being protected. Most structures in Delaware protect some amount of marsh habitat. This habitat can be greatly affected through changes in the geomorphology resulting from tidal flushing, and fauna and flora impacts due to salinity changes. Failure of dikes that are part of a wetland impoundment system may result in the loss of globally important habitat for migratory bird species.

By controlling tidal exchange, some structures currently prevent the release of hazardous materials trapped in the marsh sediment as a result of chemical spills and pollution. These toxins could potentially be carried away from flooded properties and distributed throughout the flood plain. Additionally, industrial, municipal, and agricultural operations that are flooded could release pollutants such as chemicals, solid wastes, raw sewage, and petroleum products and common household substances into the flood waters.

## **Emergency Service Facilities**

Emergency service facilities include fire and rescue stations, ambulance and paramedic stations, police stations, and emergency operation centers.

Fire and rescue stations are structures that house and maintain fire and rescue equipment and may contain communication centers and ancillary equipment storage. Ambulance and paramedic stations are structures that house and maintain EMS apparatuses and may contain communication centers and ancillary equipment storage. These structures may or may not be co-located with fire stations. Police stations are structures that house and maintain police operations, including offices, communications, and equipment storage. These structures include any Federal, Delaware Department of Natural Resources and Environmental Control, or U. S. Fish and Wildlife enforcement locations. Emergency operation centers are structures that house emergency operation personnel, communication centers, and data links.

Emergency service facilities may be adversely impacted by sea level rise. Facilities may initially be subject to intermittent flooding from lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem could become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise. Exposure of emergency service facilities to future sea level rise was assessed by using GIS point layers obtained from the United State Department of Homeland Security and the Delaware Emergency Management Agency. The layers marked the locations of emergency facilities throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility will be able to function. To fully assess the impact sea level rise will have on emergency service facilities, additional criteria will be needed including: surrounding road elevations to determine accessibility to facilities; floor elevations to determine level of inundation within structures; critical equipment elevations to determine exposure of ancillary equipment.

Statewide, eight fire & rescue stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 9% of the stations in the state (Table 41). Sussex County has the highest number of fire & rescue stations at risk, with four facilities being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with only one station being exposed at the 1.5 meter scenario. The fire & rescue stations that will be potentially exposed to sea level rise are Wilmington Fire Station 2, Leipsic Fire Station, Bowers Fire Station, Little Creek Fire Station, Indian River Fire Station, Memorial Fire Station, and Bethany Beach Stations 1 & 2. See Map Appendix for map.

Table 41 - Number of Fire & Rescue Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
County	iotai Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	88	0	0	8	0%	0%	9%
New Castle	40	0	0	1	0%	0%	3%
Kent	19	0	0	3	0%	0%	16%
Sussex	29	0	0	4	0%	0%	14%

Source: DHS (TechniGraphics), Delaware fire Stations Q1, 2008-04-02

Statewide, two ambulance & paramedic stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 3% of the stations in the state (Table 42). Both stations are located in Kent County and are only potentially exposed at the 1.5 meter scenario. New Castle and Sussex Counties have no impacted facilities. The ambulance & paramedic stations that will be potentially exposed to sea level rise are Bowers EMS/Fire Station and Leipsic EMS/ Fire Station. See Map Appendix for map.

Table 42 - Number of Ambulance & Paramedic Stations (EMS) Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	68	0	0	2	0%	0%	3%
New Castle	34	0	0	0	0%	0%	0%
Kent	15	0	0	2	0%	0%	13%
Sussex	19	0	0	0	0%	0%	0%

Source: DHS (TechniGraphics), Delaware Emergency Medical Services Q108, 2008-04-02

Statewide, five police stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 8% of the stations in the state (Table 43). Sussex County has both the highest number and highest percentage of police stations at risk, with between 9% - 14% of its stations being located within a mapped sea level rise area. Both New Castle and Kent Counties are projected to each have one police station impacted. The police stations that will be potentially exposed to sea level rise are Dewey Beach, Bethany Beach, South Bethany, USFWS Office of Law Enforcement, and DNREC Fort Delaware State Park Ranger Station. Other police stations with the potential to be exposed to sea level rise not included in the assessment are Ferwick Island and the City of New Castle. See Map Appendix for map.

Table 43 - Number of Police Stations Exposed to Sea Level Rise

Carret	Total Number	Nu	Number Inundated			Percent of Total Inundated		
County	County Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	63	0	3	5	0%	5%	8%	
New Castle	24	0	0	1	0%	0%	4%	
Kent	17	0	1	1	0%	6%	6%	
Sussex	22	0	2	3	0%	9%	14%	

Source: DHS (Technigraphics), Delaware Law Enforcement 2009 O4, 2009-12-18

Statewide, one emergency operation center is within an area that could be inundated by 1.0 meter of sea level rise, representing 14% of the centers in the state (Table 44). The site is in New Castle County and is the location for the new Wilmington emergency operation center which is currently under construction. See Map Appendix for map.

Table 44 - Number of Emergency Operation Centers Exposed to Sea Level Rise

County	T-4-1 N b	Nur	Number Inundated			Percent of Total Inundate		
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	7	0	1	1	0%	14%	14%	
New Castle	5	0	1	1	0%	20%	20%	
Kent	1	0	0	0	0%	0%	0%	
Sussex	1	0	0	0	0%	0%	0%	

Source: DEMA, EOC shapefile, 2011-04-03 [edit by Delaware Coastal Programs]

Potential Economic Impact: Limited or changed functionality of emergency service facilities could impact emergency response times and thus could cause more damage to property and possessions and increase the cert of insurance. Sea level rise may also alter governmental funding allocated to stations based on response times. Property values in impacted communities may decrease due to the lack of emergency service coverage.

Potential Social Impact: The role of emergency services facilities is to be multifaceted first responders, answering fire, rescue, hazardous materials, medical, and criminal calls. Limited or changed functionality of emergency services facilities will impact the response times of personnel and thus could increase the risk of loss of life and possessions. Delaware communities rely on these facilities and sea level rise may prevent responders from alding residents during times of need. Fire stations sometimes serve as town gathering locations for social events and local government meetings. The loss of such facilities may erode the sense of community for many towns throughout Delaware.

Potential Environmental impact: Limited or changed functionality of emergency service facilities will impact response times of personnel and thus could increase times to contain spills and other detrimental environmental impacts from fires, accidents, or chemical spills. A reduced ability to respond to hazardous waste emergencies may harm the surrounding natural habitat and contaminate water sources.

#### **Evacuation Routes**

Included in this section are roadways that are listed as evacuation routes by the Delaware Department of Transportation. Interstates and arterials tend to serve as major evacuation routes for emergencies. This substantial reliance on a single mode of transportation may endanger many people if the highway infrastructure is damaged or made inaccessible because of sea level rise. If the relative sea level increases such that portions of evacuation routes are under water then the essential connectivity and evacuation provided by those highways would be lost (CCSP, 2008).

Evacuation routes that lie in the path of sea level rise may be adversely impacted. Routes may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access and congestion problems as well as flood damage if evacuation routes are not adequately elevated or flood protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of evacuation routes to future sea level rise was assessed by using GIS line layers obtained from the Delaware Department of Transportation's Traffic Management Team. The layers marked the locations of evacuation routes throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a route is within an area that is potentially exposed to sea level rise and should not be used to determine if a road will be able to function. To fully assess the impact sea level rise will have on evacuation routes, additional criteria will be needed including: road construction materials and structures; traffic count; and the availability of other evacuation routes.

Statewide, approximately 50 miles of designated evacuation routes are within an area that could be inundated by 1.0 meter of sea level rise, representing 4% of the evacuation routes in the state (Table 45). Sussex County has the highest amount of evacuation routes at risk, with approximately 40 miles being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with only 2% of its evacuation routes being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 45 - Miles of Evacuation Routes Exposed to Sea Level Rise

C	Total Miles	Miles Inundated			Percent of Total Inundated		
County	Total Miles	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,185	12.60	48.2	65.8	1%	4%	6%
New Castle	359	2.2	4	6.8	1%	1%	2%
Kent	307	8.8	16.5	20.5	3%	5%	7%
Sussex	519	1.6	27.7	38.5	< 1%	5%	7%

Source: DelDOT Traffic Management Team (Edwards and Kelcey), 2007 Evacuation Routes, 2010-15-04

Potential Economic Impact: Limited or changed functionality of evacuation routes may impact the cost of repairs and increase insurance rates of coastal towns that could be isolated due to road inundation. Property values may also decline and industries may decide to relocate due to the potential of residents and workers getting stranded during an emergency situation. The result will be an erosion of tax revenue for the local communities impacted.

Potential Social Impact: Socially, limited or changed functionality of evacuation routes may increase the potential for loss of life or property damage due to accessibility issues. It is worth noting that the loss of a small individual segment of a given highway may make significant portions of that evacuation route impassable. Further, even if a particular interstate or arterial is passable, if the feeder roads are flooded, then the larger roads become less usable (CCSP, 2008). The result would be entire communities cut-off from access to evacuation routes. Many coastal towns in Delaware have only one major road, Route 1, which also serves as the primary evacuation route. Limited access to the roadway would isolate residents and prevent help from entering the town.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of evacuation routes may delay the removal of hazardous materials and other items from areas that are exposed to sea level rise increasing the risk for contamination. Also, permanent inundation may force the relocation of evacuation routes causing habitat destruction where these new routes are constructed.

### Transportation

### DART Bus Routes & Stops

DART First State provides transportation services statewide with over 400 buses, 57 year- round bus routes, and paratransit services. DART also provides bus route services in the beach resort section of Sussex County during the summer months.

Many Delawareans rely on public transportation to get to and from work, school, or daily activities. If relative sea level increases to an extent that transit service would pass through areas under water in the future, either the connectivity provided by that transit would be lost or corrective actions to reroute the transit would be needed (CCSP, 2008). DART bus routes and stops that lie in the path of sea level rise may be adversely impacted. Routes and stops may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if stops are not adequately elevated or prepared for flooding conditions. However, as sea levels continue to rise; the problem will become chronic, meaning adaptation will likely be required to maintain fully functionality of the public transportation system.

Exposure to Sea Level Rise. Exposure of DART bus routes and stops to future sea level rise was assessed by using GIS line and point layers obtained from the Delaware Department of Transportation. The layers marked the locations of routes and stops throughout the state. The data was analyzed with respect to the future sea level rise funndation scenarios.

It is important to note that this simple assessment tells us only whether a route or stop is within an area that is potentially exposed to sea level rise and should not be used to determine if a route or stop will be able to function. To fully assess the impact sea level rise will have on bus routes and stops, additional criteria will be needed including: route ridership; ridership numbers at individual stops; alternate route possibilities; and whether served communities will also be affected by sea level rise.

Since the vast majority of transit service is provided by buses, schedules and routes can be modified easily, though the same is not true for terminals and maintenance facilities. Therefore, minimal impact on bus systems is expected from relative sea level rise (CCSP, 2008).

Statewide, approximately 70 miles of DART bus routes are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% of the bus route mileage in the state (Table 46). New Castle County has the highest number of bus routes at risk, with approximately 94 miles being located within a mapped sea level rise area. Kent and Sussex Counties are projected to have a minimal impact from sea level rise with less than 1% of the bus routes in each county being exposed at the 1.5 meter scenario; however, the miles of bus routes analyzed in Sussex County does not include seasonal beach resort routes providing service to Rehoboth Beach, Dewey Beach, Bethany Beach, and Fenwick Island during the summer months. See Map Appendix for map.

Table 46 - Miles of DART Bus Routes Exposed to Sea Level Rise

County	Total Miles	Mi	les Inundate	ed	Percent of Total Inundated			
	rotal wiles	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	4,408	37	70	101	1%	2%	2%	
New Castle	3,299	36	66	94	1%	2%	3%	
Kent	652	0.8	2	4	< 1%	< 1%	<1%	
Sussex	456	0.5	2	3	< 1%	< 1%	<1%	

Source: DelDOT - DART, DTC TRAPESE Routes and Stops, 2010-10-01

Statewide, 69 DART bus stops are within an area that could be inundated by 1.0 meter of sea level rise, representing approximately 2% of the bus stops in the state (Table 47). Sussex County has the highest amount of bus stops at risk with approximately 48 stops being located within a mapped sea level rise area. Kent County is projected to have the smallest impact with only 2 stops potentially exposed at the 1.5 meter scenario. The DART bus stops exposed in Sussex County include seasonal beach resort stops providing service to Rehoboth Beach, Dewey Beach, Bethany Beach, and Fenwick Island during the summer months. See Map Appendix for map.

Table 47 - Number of DART Bus Stops Exposed to Sea Level Rise

County	TN.	Nur	nber Inunda	ted	Percent of Total Inundated			
	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	3,409	24	69	108	1%	2%	3%	
New Castle	2,550	14	28	58	1%	1%	2%	
Kent	555	0	2	2	0%	< 1%	< 1%	
Sussex	304	10	39	48	3%	13%	16%	

Source: DelDOT - DART, DTC TRAPESE Routes and Stops, 2010-10-01

#### Potential Economic Impact:

Changes to or elimination of DART bus routes and stops due to sea level rise would potentially cause added expenses to passengers if other means of transportation must be arranged. Additionally, alternate routes may be more costly to operate for the state and may lead to longer travel times resulting in a decrease in ridership and revenue. Allowing buses to continue to operate in known inundated areas may increase service requirements due to salt corrosion to vehicles.

Potential Social Impact: Socially, changes to or the elimination of DART bus routes and stops may impact the ability of members of the public to commute due to stops being moved away from coastal communities. Diverted routes may also increase travel time along routes causing individuals to miss appointments and have less time to perform daily tasks.

The majority of DART services are provided by buses which allows for schedules and routes to be modified easily. Therefore minimal impact on bus systems is expected from sea level rise.

Potential Environmental Impact. While minimal impact from sea level rise is expected, limited or changed functionality of DART bus routes may increase air pollution from longer altered bus routes. Additionally, contaminants, that accumulate on the pavement at bus stops, such as transportation fuel, may migrate and enter water supplies due to inundation of the impervious surfaces.

### Navigation Aids

A navigation aid is any device external to a vessel specifically intended to assist navigators in determining their position or safe course, or to warn of dangers or obstructions to navigation. Buoys, lights, and other devices are used to aid in the navigation of Delaware avetneways. Since navigation aids are situated on the water, impacts from sea level rise should be expected. Infrastructure may initially be subject to intermittent flooding from lunar high tides. This may cause short-term usage problems if navigation aids are not properly elevated. The problem may become more chronic as sea levels continue to rise; however, adaptation may not be required if full functionality of the devises remains.

Exposure to Sea Level Rise. Exposure of navigation aids to future sea level rise was assessed by using GIS point layers obtained from the U.S. Department of Homeland Security. The layers marked the locations of navigation aids throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a navigation aid is within an area that is potentially exposed to sea level rise and should not be used to determine if a navigation aid will be able to function. To fully assess the impact sea level rise will have on navigation aids, additional criteria will be needed including: type of navigation aid (floating or non-floating aid), type and length of mooring or other method of securing, and water depth at location.

Statewide, approximately 456 navigation aids are within an area that could be inundated by 0.5 meters of sea level rise, representing 100% of the aids in the state (Table 48).

Table 48 - Number of Navigation Aids Exposed to Sea Level Rise

County	T-4-131	Nun	nber Inundat	ed	Percent of Total Inundated			
	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	456	456	456	456	100%	100%	100%	
New Castle	287	287	287	287	100%	100%	100%	
Kent	62	62	62	62	100%	100%	100%	
Sussex	107	107	107	107	100%	100%	100%	

Source: Department of Homeland Security, HSIP Freedom, 2011.

Potential Economic Impact: Concerning the economy, limited or changed functionality of navigation aids may increase the risk of property damage. Most navigation aids are designed to withstand the effects of sustained sea water attack meaning the majority of devices will only see minor impacts from sea level rise. It is not expected that sea level rise will have an impact on floating navigation aids such as light vessels and buoys. The only issue may be the need to lengthen the anchor chain and strengthen the mooring. An increase in sea level may deepen and open new channels allowing for additional shipping traffic which will require the installation of more navigation aids.

Potential Social Impact: Socially, limited or changed functionality of navigation aids may increase risk of injury due to the loss of devices.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of navigation aids may increase the risk of cargo losses or fuel leaks from ships running aground. As sea level rises, new shipping routes may open but also affect the movement of sub-surface sandbanks. If and when change occurs, it may require the relocation of floating navigation buoys to a new position impacting the surrounding natural habitat.

### Port of Wilmington

The Port of Wilmington is a full-service deep-water port and marine terminal capable of handling all types of cargo with customized logistics. Today, the port is the busiest terminal on the Delaware River handling about 400 vessels annually with a yearly import/export cargo tonnage of over 4 million tons (Port of Wilmington, 2006).

The Port is considered the nation's leading gateway for imports of fresh fruit, juice concentrate, and is one of the world's largest banana hubs. Companies such as Dole Fresh Fruit Company and Chiquita Fresh North America are major importers and take advantage of the on-site cold storage complex (Port of Wilmington, 2006). Wilmington is also a leading automobile export hub to Central America, the Middle-East, and West Africa shipping vehicles for companies such as General Motors.

In addition, a variety of break bulk and bulk cargos move through the Port including forest products, steel, bulk materials, and petroleum products (Port of Wilmington, 2006). In recent years, Wilmington has also become a gateway for livestock, project cargo, and wind energy shipments.

Located at the confluence of the Delaware and Christina Rivers, 65 miles from the Atlantic Ocean, the Port of Wilmington is owned and operated by the Diamond State Port Corporation, a corporate entity of the state of Delaware (Port of Wilmington, 2006). The property includes docks, cargo transfer areas and some warehouses. Adjoining properties are used to support port operations including dredge disposal sites, warehouses, and cargo holding areas.

Port of Wilmington infrastructure may be adversly impacted by sea level rise. Facilities and equipment may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if facilities are not adequately elevated or flood proofed (Deyle, Bailey, & Matheny, 2007). However, as sea levels continue to rise, the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of the Port of Wilmington to future sea level rise was assessed by using GIS polygon layers obtained from New Castle County tax parcel maps. The layers marked the locations of Diamond State Port Corporation property throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a section of the Port of Wilmington is within an area that is potentially exposed to sea level rise and should not be used to determine if the port will be able to function. To fully assess the impact sea level rise will have on the Port of Wilmington, additional criteria will be needed including: layout of facility including warehouses, offices, storage, parking, and work areas; type and location of cargo storage areas; floor and critical equipment elevations; surrounding road and rail elevations to determine accessibility; and geotechnical information to determine soil load bearing capacities.

Approximately 128 acres of the Diamond State Port Corporation's core property are within an area that could be inundated by 1.0 meter of sea level rise, representing 55% of the port's land area (Table 49). All exposure to sea level rise is concentrated in New Castle County with approximately 158 acres being located within a mapped sea level rise area.

Table 49 - Acres of the Diamond State Port Corporation Property Exposed to Sea Level Rise

County Total Ac	Total Assoc	Acres Inundated Percent of Total				t of Total Inc	ındated
County	Total Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
New Castle	216	78	128	158	36%	59%	73%

Source: New Castle County, NCC Tax Parcels. 2010-09-01

Approximately 362 acres of the Port of Wilmington's operations and supporting activity properties are within an area that could be inundated by 1.0 meter of sea level rise, representing 29% of the port's supporting activity land area (Table 50). The Port of Wilmington's core property (Table 50) is also included in this assessment.

Table 50 - Acres of Port Operations and Supporting Activity Exposed to Sea Level Rise

County	Total Acres	Ad	res Inundat	ed	Percen	t of Total Inc	ındated	1
County	Iotal Acres	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	į.
New Castle	1,234	251	362	462	20%	29%	37%	

Source: DNREC - Office of the Secretary, Coastal Zone Heavy Industry, unpublished

Potential Economic Impact: Limited or changed functionality of the Port of Wilmington and supporting facilities may temporarily or permanently affect the needed workforce causing a loss of jobs to the region. The port may also see a decrease in revenues due to sea level rise impacting importing/exporting operations which will have an effect on city, county, and state tax revenues.

For facilities that are not appropriately protected, either by elevation or by structures, rising water levels pose an increased risk of chronic flooding, leading in the worst case to permanent inundation of marine terminal facilities, either completely or in part, and rendering them inoperable (CCSP, 2008).

Navigable depths are likely to increase in many harbors and navigation channels as a result of rising sea levels. This could lead to reduced dredging costs, but higher costs where rising water levels require changes to terminals (CCSP, 2008). Transportation costs may also increase due to impacts to supporting businesses (auto, chemical, food, minerals, etc.) which may impact the prices consumers pay for products.

One impact of sea level rise not generally mentioned is the decreased boat clearance under bridges. Even with precise timing of the stage of tide and passage under fixed bridges, sea level rise will affect the number of low water windows available for the large vessels now being built (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Potential Social Impact: Socially, changed functionality of the Port of Wilmington may impact the safety of workers due to flooding and/or compressed loading/unloading windows. The possibility remains that as sea levels rise, Diamond State Port Corporation may have to decrease the number of people employed at the port which could result in the deterioration of neighboring communities. Since the Port of Wilmington is a major part of the Delaware economy, measures to keep the facility operational will be of great importance; however, sea level rise may force the relocation of port services. Impacts on highways and rail connections could also affect the ability to utilize and transport goods to and from the Port of Wilmington (CCSP, 2008).

Potential Environmental impact: Along with fruit and vehicle imports and exports, the Port of Wilmington also ships and stores hazardous materials such as petroleum products. Inundation from sea level rise may allow stored materials to escape into the surrounding area. These products may contaminate drinking water supplies, natural habitat, and residential properties that border port facilities.

#### Railroad Lines

Railroad lines, including both passenger and freight, are infrastructure that is vital to the economic and social wellbeing of Delaware. Rail lines serve as a mode of transporting people across the Mid-Atlantic and are essential for moving freight throughout Delaware and to other parts of the United States. Impacts to the State's rail network could serve as choke points to both passenger and freight traffic that originates in and flows through Delaware (CCSP, 2008). Transportation routes serve as the lifeline to communities, and inundation of even the smallest component of a rail system can result in a much larger system shutdown (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Railroad lines are often found in low-lying areas, and therefore, are at risk for interruptions in service due to inundation and coastal erosion resulting from sea level rise. In addition, railroads often run through marsh areas in coastal zones and as the low-lying tracks become flooded; the marsh bods become vulnerable to sinking from the compaction of marsh peat (Titus, 2002). These impacts may cause short-term access and congestion problems as well as flood damage if railroad tracks are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of railroad lines to future sea level rise was assessed using GIS line layers obtained from the United States Geological Survey's 7.5 minute Digital Rail Line Graphs. The layers mark the locations of rail lines throughout the state. The data was analyzed with respect to the future sea level discounted the properties.

It is important to note that this simple assessment tells us only whether a rail line is within an area that is potentially exposed to sea level rise and should not be used to determine if a rail line will be able to function. To fully assess the impact sea level rise will have on railroad lines, additional criteria will be needed including: geo-technical information on soils; weight of trains; speed of trains/ rail/tie/ballast construction materials and methods; and depth of standing water (relates to axle heights).

Statewide, approximately 17 miles of rail lines are within an area that could be inundated by 1.0 meter of sea level rise, representing 4% of the railroad lines in the state (Table 51). New Castle County has the highest amount of rail lines at risk, with approximately 21 miles being located within a mapped sea level rise area. Kent County is projected to have the least impact from sea level rise with less than 1% of the rail lines being exposed at the 1.5 meter scenario. See Map Appendix for map.

When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 8.7 miles of rail lines potentially inundated by sea level rise, representing approximately 5% of the total (WILMAPCO, 2011). The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used data appropriate for the statewide scale of the study, while the WILMAPCO vulnerability assessment used more regionally specific data.

Table 51 - Miles of Railroad Lines Exposed to Sea Level Rise

County	Total Miles	Mi	ies Inundate	d	Percent of Total Inundated			
	lotal Willes	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	418	9	17	25	2%	4%	6%	
New Castle	235	8	14	21	3%	6%	9%	
Kent	76	0	0.03	0.1	0%	< 1%	< 1%	
Sussex	107	1	3	4	1%	3%	4%	

Source: USGS, 7.5 minute Digital Line Graphs - Rail, 2010-09-30

Potential Economic Impact: Damage to railroad lines resulting from sea level rise may increase shipping costs of freight and prices for passenger travel. Since goods are transferred to and from facilities by rail, service interruptions on selected segments of infrastructure are likely to affect a larger percentage area due to the distribution to network connectivity (CCSP, 2008). This may cut-off industries served such as the Edgemoor and Indian River power plants, the Delaware City refinery, and the Edgemoor Rail Yard bulk transfer. Concerning passenger travel, disruptions and possible restrictions to the Amtrak Northeast Corridor rail line will potentially disrupt travel between Washington D.C. – Philadelphia – New York City – Boston forcing commuters and business travelers to find other means of transportation.

For rail line systems in Delaware, sea level rise could potentially be a serious issue. Relocating tracks and permanent facilities is a major undertaking; tracks would need to be protected or moved to higher ground to remain functional (CCSP, 2008). The engineering costs of such a project may force the permanent abandonment of some routes. Some industries, such as the Port of Wilmington, need to remain at or near the water's edge to send and receive shipments. There will be a continued need for rail service into these locations. Other rail customers, however, may begin to relocate to higher ground or to different regions entirely. This will have an impact on state tax income, jobs in impacted communities, and affect the type and scale of the rail network needed to meet the demand for inbound and outbound freight shipments.

Potential Social Impact: Damage to railroad lines from sea level rise may impact the prices and amount of products available to consumers. If rail lines are inundated, more freight and passengers may have to use cars, buses, and trucks as an alternate form of transportation. The disruption of commuter lines may have an impact on job opportunities in Delaware due to individuals not being able to commute to their place of employment.

An issue related to moving rail lines further away from coastal areas is that it will, in most cases, move passenger rail services further away from population centers. The highest density populations tend to occur along coastal regions, making it the most desirable location for passenger rail stations. If the rail line is moved further inland to areas with lower population density, it would have a negative impact on the amount of patrons the rail line can service and the potential of any future commuter passenger rail line that might be warranted by population growth along the coast (CCSP, 2008).

Potential Environmental impact: Sea level rise impacts to railroad lines may cause added air pollution from alternate forms of shipping or public transit. Hazardous materials, such as creosote, originating from rail bed materials may contaminate ground and surface waters due to an increase in migration potential from inundation. Another factor is the extent to which rising sea levels create a higher water table that leads to additional flooding during periods of normal precipitation. As the water table rises, the ground is less able to absorb normal rainfall. This could cause frequent flooding of rail track and facilities (CCSP, 2008).

#### Public Boat Ramps & Piers

Delaware is home to miles of coastline, ponds, and streams making the state an exceptional destination for all types of boating and fishing. The Delaware Department of Natural Resources and Environmental Control's Division of Fish and Wildlife provides public access to boat ramps and piers throughout the state. Since ramps and piers are built along the waterfront, impacts from sea level rise should be expected. Infrastructure may initially be subject to intermittent flooding from Junar high tides. This may cause short-term access problems to parking as well as flood damage if ramps and piers are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation may be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of ramps and piers to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resources and Environmental Control's Division of Fish & Wildiffe. The layers marked the locations of state owned ramps and piers throughout Delaware. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a ramp or pier is within an area that is potentially exposed to sea level rise and should not be used to determine if a ramp or pier will be able to function. To fully assess the impact sea level rise will have on ramps and piers, additional criteria will be needed including: type of construction of ramp or pier; type and location of parking area; location of access roads to boat launch site.

Statewide, approximately 46 ramps or piers are within an area that could be inundated by 1.0 meter of sea level rise, representing 64% of the state owned ramps and piers in the state (Table 52). Percentage wise, New Castle County has the greatest amount of ramps or piers at risk, with approximately 94% of the County's ramps and piers being exposed at the 0.5 meter scenario. Kent and Sussex Counties have the greatest number of ramps and piers at risk, with approximately 17 affected ramps or piers. See Map Appendix for map.

Table 52 - Number of Ramps and Piers Exposed to Sea Level Rise

County	Total Number	Nun	nber Inundat	ed	Percent of Total Inundated			
	Iotal Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	72	43	46	50	60%	64%	69%	
New Castle	17	16	16	16	94%	94%	94%	
Kent	28	14	15	17	50%	54%	61%	
Sussex	27	13	15	17	48%	56%	63%	

Source: DNREC - fish and Wildlife, Ramps and Piers 2008-06-03, unpublished

Potential Economic Impact. Inundation from sea level rise of public boat ramps and piers may cause a reduction in water activities (fishing, birding, etc.) due to accessibility issues, resulting in a loss in state and retail revenues. Additional funds may be needed to build new structures to keep pace with rising water levels.

Sea level rise may lead to some economic benefits by exploiting new opportunities. Deeper waters may allow certain rivers and harbors to become more practical for recreational use.

Potential Social Impact: Socially, fimited or changed functionality of public boat ramps and piers may impact the ability of the public to access certain waterways safely. To many coastal communities in Delaware, life is based around fishing and boating. Limiting access to these recreational opportunities may reduce the quality of life residents and visitors expect.

Potential Environmental Impact: Economically, limited or changed functionality of public boat ramps and piers may harm the surrounding environment from the use of unauthorized access locations. Boating and fishing infrastructure may be damaged or destroyed by sea level rise, allowing materials to become an environmental hazard to surrounding wildlife and natural habitats.

### Roads & Bridges

Roads and bridges are essential infrastructure that can guide development patterns for centuries. The ability of Delaware to adapt to sea level rise in the years to come may be helped or hindered by the decisions state transportation officials make today (Titus, 2002). Transportation infrastructure is designed to perform for a wide range of service lives. Roads are among the shortest-lived facilities, with surfaces that must be repaved every 10-20 years (Transportation Research Board, 2008). Due to the limited lifespan of roads, future decisions need to be based on the cost/benefit of continued road upgrades in flood-prone areas. Transportation routes serve as the lifeline to communities, and inundation of even the smallest component of a road system can result in a much larger system shutdown (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Roads provide the public access to services and act as the major source of transportation in Delaware. In many low-lying communities, roads are lower than the surrounding lands, so that land can drain into the streets. As a result, the streets are the first to flood. As sea level rises, these drainage systems become less effective, causing additional flooding (Titus, 2002).

Sea level rise directly affects travel on roadways as a result of flooding, inundation, erosion of road bases, removal of sediment around bridge abutments or piers, and reduced bridge clearance. Roads and bridges that lie in the path of sea level rise may be adversely impacted. A road system may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access and congestion problems as well as flood damage if roadways are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of roads and bridges to future sea level rise was assessed using GIS line layers obtained from the Delaware Department of Transportation's road centerline file. The layers marked the locations of all roads and bridges throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a road or bridge is within an area that is potentially exposed to sea level rise and should not be used to determine if a road or bridge will be able to function if inundated. To fully assess the impact sea level rise will have on roads and bridges, additional criteria will be needed including: road/bridge construction, geo-technical data, traffic counts, availability of other routes, and infrastructure along the route.

Statewide, approximately 484 miles of roads and bridges are within an area that could be inundated by 1.5 meter of sea level rise, representing 4% of the roads in the state (When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 27.9 miles of roadway potentially inundated by sea level rise, representing 2.7% of the total (WILMAPCO, 2011). While the miles exposed for each assessment differ, the percentage of total inundated are relatively similar with 2% - 2.7% of the resource impacted. The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used DeIDOTs road centerline file which includes all roads in the state while the WILMAPCO vulnerability assessment only considered roadways that had corresponding traffic data. This included all major roads but left out some local roadways accounting for the difference in the number of miles inundated.

Table 53Sussex County has the highest amount of roads and bridges at risk, with approximately 357 miles being located within a mapped sea level rise area. Percentage-wise, New Castle County is projected to have the least impact from sea level rise with 2% of the County's roads being exposed at the 1.5 meter scenario. See Map Appendix for map.

When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 27.9 miles of roadway potentially inundated by sea level rise, representing 2.7% of the total (WILMAPCO, 2011). While the miles exposed for each assessment differ, the percentage of total inundated are relatively similar with 2% - 2.7% of the resource impacted. The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used DelDOT's road centerline file which includes all roads in the state while the WILMAPCO vulnerability assessment only considered roadways that had corresponding traffic data. This included all major roads but left out some local roadways accounting for the difference in the number of miles inundated.

Table 53 - Miles of Roads & Bridges Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated			
	Total Miles	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	8,990	116	317	484	1%	4%	5%	
New Castle	3,431	21	46	72	1%	1%	2%	
Kent	2,003	16	35	55	1%	2%	3%	
Sussex	3,556	79	237	357	2%	7%	10%	

Source: DelDOT, Road Centerline file, 2008-06-01

Potential Economic Impact: Concerning the economy, road networks exist to facilitate the movement of goods and are an integral part of Delaware's economic fabric. The need for these networks, or transportation demand, therefore, is defined by economic considerations that connect population centers and provide access to resources (CCSP, 2008). Since goods are transferred to and from locations via trucks, service interruptions on selected segments of road infrastructure are likely to affect a larger percentage area due to the distribution in network connectivity. Limited or changed functionality of roads may affect the amount of income and subsequent taxes paid by businesses situated along transportation routes.

Potential Social Impact: Limited or changed functionality of roads and bridges may increase the potential for loss of life or property damage and may force the re-location of land uses due to loss of access. As residential populations relocate from affected areas, demand for transported goods would decline. Similarly, as commercial activities relocate, transportation services would shift with them causing labor shortages for transportation and commercial facilities along the coast (CCSP, 2008). It is worth noting that the potential loss of a small individual segment of a given highway may make significant portions of the road network impassable. Further, even if a particular interstate or arterial is passable, if the feeder roads are flooded, then the larger roads become underutilized possibly isolating communities along the Delaware coastline. Highways are the chief mode for transporting people across Delaware. Impacts to the highway network could serve as choke points to passenger traffic that emanates in or flows through the region causing more traffic congestion (CCSP, 2008).

Potential Environmental Impact: Sea level rise may have an increased impact of coastal erosion on roadways. The effect of increased wave action, tidal currents and extreme storm surges can cause the removal of sediment in and around roadways, making them inaccessible (Transportation Research Board, 2008). Limited or changed functionality of roads and bridges may increase the risk of environmental damage from hazardous materials being transported on alternate roads due to flooding. Inundation of roadways may also result in the dispersion of paving materials into water sources. As the sea level rises, the coastline will change. Bridges that were not previously at risk may be exposed in the future. Additionally, bridges with decks at an elevation below the likely crest of storm surges, based on experience from previous storms, will be below water during the storm event and not subject to wave damage (CCSP, 2008).

### Utilities

#### Septic Tanks & Disposal fields

A septic system is a self-contained underground wastewater treatment system that treats and disposes of household wastewater onsite. The system consists of two main parts: a septic tank and the drainfield. Septic systems are often more economical than centralized sewer systems in rural areas where lot sizes are larger and houses are spaced widely apart. By using natural processes to treat wastewater onsite, septic systems do not require the installation of miles of sewer lines, making them less disruptive to the environment (WVU, 2012).

Three primary components govern the placement of a septic system: (1) the elevation of the site above groundwater, (2) the lateral distance between the leaching component of the facility and a point of water use (well, surface water, etc.), and (3) the suitability of the soils or sediments to receive and treat the liquid effluent from the wastewater disposal system (Buzzards Bay National Estuary Program, 1991). Pathogens in septic tank effluent are removed primarily through physical retention or straining through soil and adsorption onto soil particles. The efficiency of these processes decreases as the moisture in the soil increases and drops drastically if the soil is saturated (Buzzards Bay National Estuary Program, 1991). Septic systems that lie in the path of sea level rise may be adversely impacted. Systems may initially be subject to intermittent flooding from lunar high tides. This may cause short-term operational problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of septic systems to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of septic systems throughout the state. The tank location was identified as the location of the housing structure. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a tank is within an area that is potentially exposed to sea level rise and should not be used to determine if a tank will be able to function. To fully assess the impact sea level rise will have on septic systems, additional criteria will be needed including: exact locations of septic tanks and disposal fields; and groundwater elevations to determine pre-inundation effects.

Statewide, 1,600 septic systems are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% of the septic systems in the state (Table 54). Sussex County has both the highest number and highest percentage of septic systems at risk, with 1–7% of its septic systems being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with less than 1% of its septic systems being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 54 - Number of Septic Systems Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated			
	rotal Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	78,109	485	1,675	3,185	1%	2%	4%	
New Castle	15,460	7	18	44	< 1%	< 1%	< 1%	
Kent	21.095	63	243	393	< 1%	1%	2%	
Sussex	41,554	415	1,414	2,748	1%	3%	7%	

Source: DNREC, Delaware Septic Systems (last update 2010-11-23), unpublished

Potential Economic Impact: Concerning the economy, the failure of septic systems is a major challenge that property owners exposed to sea level rise will have to address. If this issue is not remedied, a home is rendered uninhabitable, and the property loses its value. In most cases, the property cannot be sold for other uses due to the level of development that has already altered the land (Maryland DNR, 2008). Above-ground facilities, such as bermed infiltration ponds, or in-ground sewage holding tanks are possible alternatives. These methods are expensive and have a limited capacity (Maryland DNR, 2008). Holding tanks must be pumped out, requiring the services of companies that specialize in sewage tank removal. This will add to the already high costs but may provide new employment opportunities. Failing septic systems may also force local governments to install costly central sewer systems for coastal communities.

Potential Social Impact: The changed functionality of septic tanks and disposal fields may impact the health and safety of communities that are exposed to untreated or partially treated waste. Sea level rise may cause some properties in coastal towns that rely on septic systems to become uninhabitable due to sewage backups. Microbial populations from septic waste that is able to enter the surface water may exceed the U.S. Environmental Protection Agency's body contact standards, abruptly halting recreational use of beaches, lakes, and streams and possibly contaminating groundwater supplies.

Potential Environmental Impact: The presence of groundwater levels near the surface will affect the integrity of on-site septic disposal systems. Saturated ground conditions impair the soil's ability to infiltrate and filter sewage effluents. Sea level rise will decrease the soil filtration process allowing for additional contaminants to enter water resources.

It is estimated that every failing septic system can discharge more than 76,650 gallons of untreated wastewater into Delaware's groundwater and surface waters per year (Lee, Jones, & Peterson, 2005). Untreated wastewater contains excessive nutrients (nitrogen and phosphorus) that can harm native plant and fish populations in surface waters. Wastewater's excessive organic matter content also can choke off the oxygen supply in streams and rivers.

#### Underground Utilities (Pipelines)

Underground pipelines for this section are designated infrastructure that carries oil or natural gas to Delaware residents and industries. These materials are transported via a network of underground pipelines running throughout the state. Pipelines are considered a safe and economical mode of transporting large volumes of product. Aging steel pipes, especially for natural gas, are being constantly replaced with high strength Polyethylene plastic pipes which are less likely to corrode; however, these new pipes may be more prone to damage associated with sea level rise such as the force of wave action.

Underground utilities that lie in the path of sea level rise may be adversely impacted. Pipelines may initially be subject to intermittent flooding from lunar high tides. This may cause short-term supply issues as well as flood damage if pipelines are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of underground pipeline to future sea level rise was assessed by using GIS line layers obtained from the United States Department of Transportation's National Pipeline Mapping System. The layers marked the locations of oil and natural gas pipeline throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a pipeline is within an area that is potentially exposed to sea level rise and should not be used to determine if a pipeline will be able to function. To fully assess the impact sea level rise will have on underground utilities, additional criteria will be needed including: material conveyed in pipeline; construction of pipeline; surrounding road elevations to determine accessibility to pipelines; elevations of pipelines and groundwater surface levels; and elevation of access points.

Statewide, approximately 17 miles of pipeline are within an area that could be inundated by 1.0 meter of sea level rise, representing 5% of the underground pipeline in the state (Table 55). New Castle County has both the highest number of miles and highest percentage of pipeline at risk, with between 7% - 9% of its pipeline being located within a mapped sea level rise area. Sussex County is projected to have the least impact from sea level with less than 1% of its pipeline being exposed at the 1.5 meter scenario. A map showing underground pipelines is not available due to the sensitive nature of the information.

Table 55 - Miles of Pipeline Exposed to Sea Level Rise

County	T-1-1150	Miles Inundated			Percent of Total Inundated			
County	Total Miles	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	347	14	17	20	4%	5%	6%	
New Castle	162	11	13	15	7%	8%	9%	
Kent	100	3	4	5	3%	4%	5%	
Sussex	84	0.18	0.34	0.47	< 1%	< 1%	< 1%	

Source: National Pipeline Mapping System, U.S. Dept. of Transportation – Pipeline and Hazardous Materials Safety Administration, 2011-07-12.

Potential Economic Impact: Concerning the economy, limited or changed functionality of underground pipelines may prevent expansion of networks and future development because of the inability to connect to current line infrastructure. Companies that manage the utility infrastructure may incur additional expenses due to the need to service damaged lines. The requirement for alternate transport methods may also increase expenses for individuals and businesses that rely on underground pipelines.

Potential Social Impact: Socially, limited or changed functionality of underground utilities may impact the amount of material that is able to be transported to consumers. Communities impacted by service disruptions could see businesses close and residential areas become uninhabitable due to the lack of energy sources.

Potential Environmental Impact: Concerning the environment, An increase in the frequency of inundation will affect soil structure, water table levels, soil stability, and the vulnerability of pipelines to normal wave action as well as storm surge. Sea level rise will cause increases in the elevation of fresh groundwater that overlies saltwater in surficial aquifers in coastal areas. This may expose buried utility fines and pipelines to corrosion and may affect the structural stability of the buried pipelines (Deyle, Bailey, & Matheny, 2007). Where significant subsidence has occurred, pipeline segments will be exposed to wave action. High-energy waves may subject a pipeline to stress levels it was not designed to withstand, causing possible fractures (Committee on Environment and Natural Resources, 2008). Spills of hazardous substances would result, leading to detrimental impacts on surrounding natural areas.

### Wastewater Facilities, Pumping Stations, & Spray Irrigation Fields

Wastewater facilities are a critical type of infrastructure in Delaware. Preserving the operational integrity of these facilities will be a key component to maintaining the quality of life and environmental quality that many Delawareans have come to expect.

Much of the water used by homes, industries, and businesses in Delaware must be treated before it is released back into the environment. The infrastructure used during wastewater treatment include: pumping stations, spray irrigation fields, and treatment/collection facilities. Pumping stations are structures that contain pumps and associated equipment that are used to move wastewater to treatment facilities. Spray irrigation fields are land areas used for the application of treated wastewater. Treatment facilities are structures and surrounding facilities (aeration basins, etc.) which are used in the processes to treat wastewater. Collection facilities are structures that collect wastewater and then move the waste to treatment facilities.

Wastewater infrastructure that lies in the path of sea level rise may be adversly impacted. Facilities may initially be subject to intermittent flooding from spring tides. This may cause short-term access problems as well as flood damage if facilities are not adequately elevated or flood proofed (Deyle, Bailey, & Matheny, 2007). However, as sea levels continue to rise, the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality. Concerning spray irrigation fields, future flooding may inhibit the treatment ability of these land areas.

Exposure to Sea Level Rise. Exposure of wastewater facilities to future sea level rise was assessed by using GIS point data layers obtained from New Castle, Kent, and Sussex Counties. The layers marked the locations of publically owned pumping stations, spray irrigation fields, and treatment/collection facilities throughout the state. The layers were analyzed with respect to the future sea level rise inundation areas. This assessment did not include private, community, and investor owned and operated wastewater facilities.

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility/field will be able to function. To fully assess the impact sea level rise will have on wastewater infrastructure, additional criteria will be needed including; surrounding road elevations to determine accessibility to facilities; floor elevations to determine the level of inundation within structures; Critical Equipment Elevations to determine exposure of pumps, controls, backup generators, and other ancillary equipment; groundwater elevations to determine changes in the depth of the vadose zone for irrigation; soil type to determine saturation rates for irrigation fields; construction of structures to determine saturation decomes saturated.

While the number of wastewater facilities exposed to sea level rise is an important consideration, understanding of the amount of homes and businesses these facilities serve is critical. With this in mind, the impact of sea level rise will extend far beyond just the limit of inundation.

Statewide, approximately 17% of pumping stations are within the 1 meter sea level rise scenario (Table 56). In New Castle and Kent County, approximately 5% - 6% of each county's pumping stations will be exposed to sea level rise at the 1.5 meter scenario. Sussex County is projected to have the greatest number of facilities impacted with approximately 13% - 37% of the county's pumping stations being exposed to sea level rise. See Map Appendix for map.

Table 56 - Number of Public Pumping Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated			
County	TOTAL NUMBER	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	648	44	111	136	7%	17%	21%	
New Castle	156	3	8	10	2%	5%	6%	
Kent	176	1	5	9	1%	3%	5%	
Sussex	316	40	98	117	13%	31%	37%	

Source: New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6-12-2009.

Only one spray irrigation field is projected to be impacted by sea level rise in Delaware. The spray irrigation field is located in Sussex County near Wolfe Neck and will be potentially exposed at the 1.5 meter scenario (Table 57).

Table 57 - Number of Public Spray Irrigation fields Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated			
County	rotal Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	6	0	0	1	0%	0%	17%	
New Castle	4	0	0	0	0%	0%	0%	
Kent	0	0	0	0	0%	0%	0%	
Sussex	2	0	0	1	0%	0%	50%	

Source: DNREC - financial Assistance Branch (TetraTech), Spray Irrigation fields, 1 -11-2010.

Statewide, approximately 7% of public wastewater treatment/collection facilities are within the 1.0 meter scenario (Table 58), No facilities will be exposed at the 0.5 meter scenario. In New Castle and Sussex County, two treatment/collection facilities in each county will be exposed to sea level rise at the 1.5 meter scenario. The wastewater treatment/collection facilities that will be potentially exposed to sea level rise are located in Delaware City, Port Penn, Lewes, and Seaford. See Map Apendix for map.

Table 58 - Number of Public Treatment/Collection Facilities Exposed to Sea Level Rise

County	Tatal Number	Nur	nber inunda	ted	Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	30	0	2	4	0%	7%	13%	
New Castle	9	0	1	2	0%	11%	22%	
Kent	6	0	0	0	0%	0%	0%	
Sussex	15	0	1	2	0%	7%	13%	

Sources: DNREC – financial Assistance Branch (TetraTech), POWWTP, 1-11-2010; New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6-12-2009.

Potential Economic Impact: Concerning the economy, limited or changed functionality of wastewater infrastructure may prevent the expansion of the state's sewer network. Development in such areas could become stagnant and businesses may have to suspend operation if wastewater facilities become non-functional.

If businesses are forced to suspend operations and development opportunities become limited, the result will be a loss of state and local tax revenue. Employment may also be impacted if wastewater facilities are impacted by sea level rise. While the number of public facilities impacted by sea level rise is relatively small, the cost of adaptation and flood prevention to maintain functionality may put a financial strain on local municipalities. These economic strains may include the cost of retrofits to facilities, the construction of new infrastructure, and an increase in the amount of funds used for storm damage.

Potential Social Impact. Limited or changed functionality of wastewater infrastructure may impact the amount of waste that is able to be moved, which may cause sewer line backups into houses. The backups may lead to home damage and health issues due to bacteria and increased dampness. In some cases when a facility is inundated, operators may be forced to bypass the treatment process and release untreated waste into nearby rivers and streams impacting water quality and recreational opportunities. The release of untreated waste may necessitate the need for wastewater storage basins which will cause odors and unpleasant views impacting the aesthetic value of the surrounding area.

Potential Environmental Impact: A wastewater facility that is being flooded, or has been flooded, can suffer structural damage due to the weight of the floodwaters. The structural damage may cause untreated wastewater to be diverted into nearby fields or bodies of water which could have a damaging effect to the local environment (Kane County, 2005). Environmental impacts may include harm to fish and wildlife populations, oxygen depletion in water, beach closures, restrictions on fish and shellfish harvesting, and contamination of drinking water (USGS, 2011). Concerning spray irrigation, the sprayed wastewater evaporates into the air, soaks into the soil, or percolates through the soil and recharges the groundwater (USGS, 2005). Sea level rise would cause an increased threat of flooding which will prevent wastewater from entering the soil profile allowing for the potential of wastewater runoff.

#### Wells - Domestic, Industrial, Irrigation & Public

Groundwater is a significant water supply source for Delaware. The amount of groundwater storage dwarfs our present surface water supply. At any given time groundwater is about 20 to 30 times greater than the amount of water in all the lakes, stream, and rivers of the United States (USGS, 2000). Groundwater is tapped through wells placed in water-bearing soils and rocks beneath the surface of the earth. Wells in Delaware supply water for domestic, industrial, irrigation, and public uses. Domestic wells constitute the largest share of all water wells in the state; however, irrigation wells account for the largest use of groundwater.

Wells that lie in the path of sea level rise may be adversely impacted. Wells may initially be subject to intermittent flooding during lunar high tides. This may cause short-term water usage problems due to salt water intrusion. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of wells to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resources and Environmental Controls Division of Water wells database. The layers marked the locations of domestic, industrial, irrigation, and public wells throughout the state. The layers were analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a well is within an area that is potentially exposed to sea level rise and should not be used to determine if a well will be able to function. To fully assess the impact sea level rise will have on wells, additional criteria will be needed including: depth of well; construction of well; height of well casing; grouting of well; location and type of pump; geo-hydrology of area in regard to salt water intrusion.

Statewide, 2,985 domestic wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 5% of the domestic wells in the state (Table 59). Sussex County has both the highest number and highest percentage of domestic wells at risk, with between 1,701 and 3,541 (5% - 10%) of its domestic wells being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with 2% of its domestic wells being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 59 - Number of Domestic Wells Exposed to Sea Level Rise

County		Number Inundated			Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	61,285	2,051	2,985	4,183	3%	5%	7%	
New Castle	6,507	85	119	129	1%	2%	2%	
Kent	19,871	265	413	513	1%	2%	3%	
Sussex	34,907	1,701	2,453	3,541	5%	7%	10%	

Source: DNREC, Division of Water. Wells Database, 2010.

Statewide, 21 industrial wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 6% of the industrial wells in the state (Table 60). Sussex County has the highest number of wells at risk with between 8 and 15 of its industrial wells being located within a mapped sea level rise area. New Castle County has the highest percentage of industrial wells at risk, with 11% of the county's wells being exposed at the 1.5 meter scenario. Kent County is projected to have the least impact with only 2 industrial wells being exposed to sea level rise. See Map Appendix for map.

Table 60 - Number of Industrial Wells Exposed to Sea Level Rise

	T	Number Inundated			Perce	Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m		
State	335	11	21	25	3%	6%	7%		
New Castle	74	3	6	8	4%	8%	11%		
Kent	82	0	1	2	0%	1%	2%		
Sussex	179	8	14	15	4%	8%	8%		

Source: DNREC, Division of Water. Wells Database, 2010.

Statewide, 48 irrigation wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 1% of the irrigation wells in the state (Table 61). Sussex County has the highest number of wells at risk with between 12 and 39 of the county's irrigation wells being located within a mapped sea level rise area. New Castle County has the highest percentage of irrigation wells at risk (3%), but this represents only four wells being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 61 - Number of Irrigation Wells Exposed to Sea Level Rise

Country		Number Inundated			Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	3,501	25	48	66	1%	1%	2%	
New Castle	145	2	3	4	1%	2%	3%	
Kent	1,006	11	17	23	1%	2%	2%	
Sussex	2,350	12	28	39	1%	1%	2%	

Source: DNREC, Division of Water, Wells Database, 2010.

Statewide, 75 public wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 6% of the public wells in the state (Table 62), Sussex County has both the highest number and highest percentage of public wells at risk, with between 18 and 105 (3% - 15%) of its public wells being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with seven (3%) of the County's public wells being exposed at the 1.5 meter scenario. See Map Appendix for map

Table 62 - Number of Public Wells Exposed to Sea Level Rise

County	Total Number	Nur	Number Inundated			Percent of Total Inu		
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	1,312	25	75	129	2%	6%	10%	
New Castle	264	1	3	7	< 1%	1%	3%	
Kent	341	6	15	17	2%	4%	5%	
Sussex	707	18	57	105	3%	8%	15%	

Source: DNREC, Division of Water, Wells Database, 2010.

Potential Economic Impact: Concerning the economy, limited or changed functionality of domestic and public water wells may prevent the expansion of water supply networks and future development due to system capacity limits. Also, the movement of groundwater in an aquifer is typically slow making it difficult and expensive to flush saltwater contamination from a groundwater source and re-establish an original freshwater/ seawater interface (USGS, 2000). Once polluted, an aquifer may remain contaminated for decades. Additional costs would arise from providing alternate water supplies to the impacted communities.

Impacts to irrigation wells may have an impact on crop production. The diminished crop yield and possible loss of agricultural land will mean a potential loss of tax revenue, primarily for state and indirectly to local governments, in the form of businesses which support the agricultural industry.

Potential Social Impact: Socially, limited or changed functionality of domestic and public water wells may impact the amount and quality of potable water available for coastal communities. A decrease in supply would cause certain areas of Delaware to become uninhabitable without an outside source of potable water. Health concerns may also arise from unsafe potable water. The U.S. Public Health Service drinking water standards indicate that a 2% concentration of seawater in fresh groundwater will make the water source unusable. Above this level, the water is considered to be contaminated and is no longer safe for public supply purposes (USGS, 2000).

Potential Environmental Impact: Concerning the environment, as sea level rises and shorelines recede landward, saltwater intrusion into coastal surficial aquifers will increase. Saltwater intrusion is the shoreward movement of water from the ocean into confined or unconfined coastal aquifers and the subsequent displacement of freshwater from these aquifers (USGS, 2000). Communities that draw water from surficial aquifers in various parts of Delaware have already experienced problems with saltwater intrusion from the sea due to excessive withdrawais. Sea level rise will exacerbate these problems. The 'salt front' of the tidal saltwater wedge in coastal rivers also will move further upstream with the potential to affect both surface water intakes and well fields in aquifers that are recharged by river water (Deyle, Bailey, & Matheny, 2007).

#### Services

#### Adult & Child Care Facilities

Adult care facilities, such as nursing homes and assisted living facilities provide temporary or long-term, non-medical residential care services for adults who are unable to live independently. Resident dependence may be the result of physical or other limitations associated with age, physical or mental disabilities or other factors. Most residents of adult care facilities are in need of supervision and personal care services necessary to enable the resident to maintain good personal health and to carry out the basic activities of daily living (New York State, 2005).

Child care facilities are licensed day care centers that provide care for children typically under the age of 13. Day care is typically an ongoing service during specific periods, such as the parents' time at work.

Adult and child care facilities that lie in the path of sea level rise may be adversely impacted. Facilities may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of adult and child care facilities to future sea level rise was assessed by using GIS point layers obtained from the University of Delaware's Center for Applied Demography and Survey Research. The layers marked the locations of facilities throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility will be able to function. To fully assess the impact sea level rise will have on adult and child care facilities, additional criteria will be needed including: surrounding road elevations to determine accessibility; floor and critical equipment elevations; facility property layout to determine areas of use and emergency exit locations; and facility use criteria (age, number, mobility of users).

Statewide, only one adult care facility is within an area that could be inundated by 1.5 meters of sea level rise, representing 1% of the facilities in the state (Table 63). The facility is a nursing home located in the Governor Bacon Health Center, near Delaware City in New Castle County.

Table 63 - Number of Adult Care Facilities Exposed to Sea Level Rise

County	Total Number	Nu	mber Inunda	ited	Percent of Total Inundated			
County	iotai Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	81	0	0	1	0%	0%	1%	
New Castle	50	0	0	1	0%	0%	2%	
Kent	11	0	0	0	0%	0%	0%	
Sussex	20	0	0	0	0%	0%	0%	

Source: UofD - CADSR, Current Adult Care Facilities, unpublished.

Statewide, nine child care facilities are within an area that could be inundated by 1.5 meters of sea level rise, representing 1% of the facilities in the state (Table 64). Sussex County has the highest number of facilities at risk, with 4 buildings being located within a mapped sea level rise area. Kent County is projected to have the least impact from sea level rise with only 1 child care facility being exposed at the 1.5 meter scenario. The only county to have child care facilities potentially exposed to sea level rise at the 0.5 and 1.0 meter scenarios is Sussex County.

Table 64 - Number of Child Care Facilities Exposed to sea level Rise

0	<b>-</b>	Nur	nber Inunda	ted	Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	1,532	2	2	9	< 1%	< 1%	1%	
New Castle	932	0	0	4	0%	0%	< 1%	
Kent	297	0	0	1	0%	0%	< 1%	
Sussex	303	2	2	4	1%	1%	1%	

Source: UofD - CADSR, Current Day Care Centers, unpublished

Potential Economic Impact: Adult and child care facility owners may need to make repairs to maintain accessibility. Also, costs for adult and child care services could increase if facilities within the sea level rise areas are forced to close. The result would be greater demand at other facilities that are not threatened by introducing.

Potential Social Impact: Socially, limited or changed functionality of adult and child care facilities could mean longer commutes for family members and less convenient care services.

Potential Environmental Impact: Environmental impacts will be limited.

#### Cemeteries

A cemetery is a land area that has been specifically designated as a burial ground for the remains of deceased individuals. The remains may be interred in a grave, a tomb, an above-ground grave, or a mausoleum. This resource does not include archeological sites or privately owned family plots.

Cemeteries that lie in the path of sea level rise may be adversely impacted. Sites may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation or site movement will likely be required to maintain full functionality.

Exposure to Sea Level Rise. Exposure of cemeteries to future sea level rise was assessed by using GIS point layers obtained from the United States Geologic Survey's Geographic Names Information System. The layers marked the locations of cemeteries throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a cemetery is within an area that is potentially exposed to sea level rise and should not be used to determine if a cemetery will be able to function. To fully assess the impact sea level rise will have on cemeteries, additional criteria will be needed including: soil type: layout of cemetery; type of burial and locations; and groundwater levels.

Statewide, three cemeteries are within an area that could be inundated by 1.5 meters of sea level rise, representing 4% of the cemeteries in the state (Table 65). The only county in the state that has cemeteries potentially exposed to sea level rise is Sussex County.

Table 65 - Number of Cemeteries Exposed to Sea Level Rise

Campby	T. t. I N b	Nun	nber Inunda	ted	Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	82	2	2	3	2%	2%	4%	
New Castle	23	0	0	0	0%	0%	0%	
Kent	18	0	0	0	۵%	0%	0%	
Sussex	41	2	2	3	5%	5%	7%	

Source: USGS, Geographic Names Information System, 2011-06-15

Potential Economic Impact: Limited or changed functionality of cemeteries may incur added expenses to reinter bodies. There are significant costs also associated with moving cemeteries to better situated sites. Another consideration is that previously sold plots may have to be refunded if a cemetery becomes permanently inundated.

Potential Social Impact: Many of Delaware's cemeteries are considered to be culturally important. Inundation of historic cemeteries will decrease the opportunity for people to learn about historical figures and Delaware's cultural heritage. Also changed functionality of cemeteries may impact the ability of relatives to visit gravesites.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of cemeteries due to rising groundwater or inundation may leach substances from older unsealed coffins, Inundation of cemeteries may result in the release of lead and other toxins that are used in burial materials contaminating surrounding natural habitats and water sources.

#### Private & Public Schools

A private school is any institution for which the facilities are not provided by the federal, state, or local government. The majority of private schools in Delaware are operated by religious institutions and organizations. Funding is generally provided through student fuition, endowments, scholarship funds, and donations and grants from sponsoring organizations. Private schools typically provide education from kindergarten through 12th grade.

A public school is an institution that is administered by the local, state, or federal government. School funding is provided through taxation and school performance is monitored by the Delaware Department of Education. The public school system provides education from kindergarten through 12th grade. The schools are structured as elementary schools, middle schools, and high schools.

Schools that lie in the path of sea level rise may be adversely impacted. Facilities may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality. The statewide exposure of schools is relatively minor with only 1 private school and no public schools projected to be impacted by sea level rise. Based on this small exposure. Delaware is likely to be resilient to any changes.

Exposure to Sea Level Rise: Exposure of private and public schools to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Education. The layers marked the locations of schools throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a school is within an area that is potentially exposed to sea level rise and should not be used to determine if a school will be able to function. To fully assess the impact sea level rise will have on private and public schools, additional criteria will be needed including: floor and critical equipment elevations; facility property layout to determine areas of outdoor use and emergency egress; facility use criteria (age, number, mobility of users); and surrounding road elevations to determine access.

Only 1 school (including both private and public) is projected to be impacted by sea level rise in Delaware. The school is St. Peters, located in the City of New Castle, and will be potentially exposed at the 1.0 meter scenario. This one school accounts for 1% of the private schools in both New Castle County and the entire state (Table SR)

Table 66 - Number of Private Schools Exposed to Sea Level Rise

County	T. (	Nu	Number Inundated			Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m		
State	149	0	1	1	0%	1%	1%		
New Castle	107	0	1	1	0%	1%	1%		
Kent	25	0	0	0	0%	0%	0%		
Sussex	17	0	0	0	0%	0%	0%		

Source: Delaware Department of Education, Delaware Private School Layer, 9-29-201

Table 67 - Number of Public Schools Exposed to Sea Level Rise

County	T-1-121	Number Inundated			Percent of Total Inundated		
	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	252	0	0	۵	0%	0%	0%
New Castle	136	0	0	0	0%	0%	0%
Kent	55	0	0	0	0%	0%	0%
Sussex	61	0	0	0	0%	0%	0%

Source: Delaware Department of Education, Delaware Public School Layer, 9-29-2010

Potential Economic Impact: Inundation resulting from sea level rise may increase the costs and expenses to maintain the impacted schools. Also, missed school days, as a result of access issues, could impact the guardians of the students by increasing the need to find alternative supervision.

Potential Social Impact: Inundation of schools resulting from sea level rise may impact the safety and learning environment of the students. Also, missed school days, as a result of access issues, could impact the guardians of students by increasing the need to finder alternative supervision.

Potential Environmental Impact: Inundation of schools resulting from sea level rise may impact the environment by allowing more pollutants to be emitted from vehicles due to longer travel times needed to reach alternate facilities.

#### Industrial

#### Brownfields

Brownfields are a subset of SIRS (Site Investigation and Remediation Section) contaminated sites. A Brownfield is defined as "any vacant, abandoned, or underutilized real property, the development or redevelopment of which is hindered by the reasonably held belief that the real property may be environmentally contaminated."[7 Del. C. §9102(3)]. The majority of brownfield sites are associated with former industrial or commercial facilities, such as gas stations, factories, and salvage yards, and are usually located in a community's commercial zone. Many brownfields in the City of Wilmington represent wetlands or subaqueous lands filled with industrial wastes that contain hazardous substances, as well as commercial and residential refuse. Brownfield sites may contain hazardous wastes that are dangerous or potentially harmful to human health and the environment. Contaminants may be found in a solid, liquid, or gaseous form contained in discarded commercial products, waste spill residues, or by-products of manufacturing processes. Contamination may be present in surface and subsurface soils, groundwater, surface water, and sediments.

Brownfields that lie in the path of sea level rise may be adversely affected. Sites may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if sites are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic. Depending on the site, contaminants could be released into the water column, change form (reduced vs. oxidized, solid and immobile vs. dissolved and mobile), and lead to potential groundwater contamination.

Exposure to Sea Level Rise: Exposure of brownfield sites to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of brownfields, registered in the State Brownfield Program, throughout Delaware. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will function or release contaminants. To fully assess the impact sea level rise will have on brownfields, additional criteria will need to be analyzed including: contaminants that are still present at the site; groundwater elevations at a given site; soil type and other geo-technical data; technical and economic feasibility of additional remediation; and proposed redevelopment use of a site.

Statewide, 23 brownfield sites are within an area that could be fully or partially inundated by 1.0 meter of sea level rise, representing 17% of the brownfield sites in the state (Table 68). In New Castle County, nearly 30% of the county's brownfields will be potentially exposed to sea level rise at the 1.5 meter scenario. Sites located in Kent County will experience no impacts while in Sussex County only one brownfield will be potentially affected by sea level rise. See Map Appendix for map.

Table 68 - Number of Brownfield Sites Exposed to Sea Level Rise

Country	Total Number	Number Inundated			Percent of Total Inundated		
County	Iotal Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	139	12	23	35	9%	17%	25%
New Castle	114	11	22	34	10%	19%	30%
Kent	12	0	0	0	0%	0%	0%
Sussex	13	1	1	1	8%	8%	8%

Source: DNREC, Brownfields GIS Layer, 2010-10-27

Potential Economic Impact: When communities convert brownfield sites, such as parking lots or vacant properties, into vibrant mixed-use developments, they can strengthen their local tax base, concentrate growth, and reduce pressure to convert undeveloped land, potentially yielding significant air and water quality benefits. Redevelopment of brownfield sites removes environmental hazards from Delaware communities and provides new investment opportunities in areas already well served by infrastructure. New development and investment in these site locations can re-energize lagging commercial corridors, providing new stimulus to preserve traditional uses and promote recreational opportunities that strengthen the local economy (NOAA, 2011). If sea level rise changes the usefulness of brownfield sites, redevelopment, and the related income produced may be prevented, reducing tax revenues for coastal towns and economic development potential.

Potential Social Impact: Sea level rise may impede the remediation and redevelopment of brownfield sites within port and coastal communities. This would have a deleterious effect in social terms. The redevelopment of brownfield sites in these locations promotes eco-tourism and eco-friendly recreational activities. These include fishing, camping, picnicking and water related activities. Brownfield sites can serve as educational facilities as well, instructing youth and non-locals as to the qualities of the natural environment. Without the opportunity to redevelop these brownfields, these sites could remain blighted areas on the landscape possibly contributing to poverty, health problems, crime, and urban sprawl in communities impacted by sea level rise. Many brownfield sites are near or adjacent to low-income communities. Sea level rise may prevent site cleanup or result in increased contamination in the community, representing a significant social and environmental justice issue.

Potential Environmental Impact: Inundation may allow above-ground contaminants to dissolve in the surface water and then seep into the soil. In a brownfield site, water is most often the media that displaces hazardous chemicals. Since sallwater is heavier than freshwater, it has a greater potential to displace contaminated groundwater plumes, pushing non-aqueous contaminants that are less dense than water upward to ground level. Sea level rise, especially saltwater intrusion, will increase this factor. Depending on the geological characteristics of a site, the direction of plume migration may be difficult to predict without a comprehensive geophysical analysis (Barnett, 2010).

Coastal communities can serve as stewards of natural resources and are better positioned to understand the ecological balance of lands comprising the public trust. These communities often share insights and knowledge of local habitats. Additionally, the changed functionality and hydrologic conditions of brownfield sites may impact the environment by allowing contaminants to escape into the surrounding media. Contaminated runoff may have a negative impact on neighboring or downstream natural habitats and wildlife species.

#### Landfills & Salvage Yards

A landfill is defined as: "A natural topographic depression and/or man-made excavation and/or diked area, formed primarily of earthen materials, which has been lined with man-made and/or natural materials or remains unlined and which is designed to hold an accumulation of solid wastes." State of Delaware Regulations Governing Solid Waste 1301:3.0

Sites included in this assessment range from state permitted landfills operated by major companies such as NRG, Waste Management and Delaware Solid Waste Authority (DSWA) to small privately or municipally owned sites, some of which are no longer in operation. Many of the smaller landfills and salvage yards are not permitted and are regulated by the DNREC Site Investigation & Remediation Section (SIRS).

The major potential effects of sea level rise on landfills and salvage yards are inundation, waste solution migration, physical erosion, and saltwater intrusion. Sites may initially be subject to intermittent flooding from lunar high tides, which may cause erosion of berms resulting in a release of contaminants. As sea levels continue to rise, inundation will become more chronic and saltwater intrusion of groundwater may occur. Both may result in structural instability and contaminant release. However, the severity of the effects of inundation is dependent on many specific factors, so this issue needs to be evaluated on a site-specific basis.

Exposure to Sea Level Rise: Exposure to landfills and salvage yards to future sea level rise was assessed by using GIS point and polygon layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of landfills and salvage yards throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will be able to function. To fully assess the impact sea level rise will have on landfills and salvage yards, additional criteria will be needed including: surrounding soil type; landfill construction including liner and cap material; status (i.e. active or capped); layout of facility including storage areas and work areas; and materials stored on-site; groundwater elevations.

Currently most of Delaware's permitted landfills are not anticipated to experience significant impacts from sea level rise. Some along water bodies could require engineering controls such as heightened barrier walls to combat storm surges, or a groundwater extraction system to prevent groundwater from coming in direct contact with the waste mass, if there was significant risk to human health or the environment to justify such measures. However, many of the non-permitted landfills/dump sites and salvage yards that have been closed are located in areas that are vulnerable to the future impacts of sea level rise.

The following tables represent both state permitted landfills and small landfills regulated by SIRS. Statewide, approximately 18% of landfills are within the 1.0 meter scenario (Table 69), however, only 2% of the total landfill acreage will be possibly impacted (Table 70). In New Castle and Kent Counties, approximately 1% to 4% of the designated landfill areas will be potentially exposed to sea level rise. Sussex County is projected to have no impacts to landfills under any scenario. The greatest number of landfills impacted by sea level rise will occur in New Castle County with the potential for 16 landfill sites to be exposed. See Map Appendix for map.

Statewide, approximately 22% of salvage yards are within the 1.0 meter sea level rise scenario (Table 71). New Castle County is projected to have approximately 11% - 45% of the county's salvage yards potentially exposed to sea level rise. Sussex County will have no salvage yards exposed to sea level rise, while Kent County only has one salvage yard potentially exposed. See Map Appendix for map.

Table 69 - Number of Landfills Exposed to Sea Level Rise

County	7.4.13	Number Inundated			Percent of Total Inundate		
	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	73	11	13	16	15%	18%	22%
New Castle	43	9	11	14	21%	26%	33%
Kent	9	2	2	2	22%	22%	22%
Sussex	21	0	0	0	0%	0%	0%

Table 70 - Acres of Landfills Exposed to Sea Level Rise

	Total Number	Nun	Number Inundated			Percent of Total Inundated		
County	y Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	943	7	16	26	1%	2%	3%	
New Castle	726	7	14	23	1%	2%	3%	
Kent	84	0.5	1	3	1%	2%	4%	
Sussex	133	0	0	0	0%	0%	0%	

Source: DNREC, Landfills GIS Layers, 2010-09-28

Table 71 - Number of salvage Yards Exposed to Sea Level Rise

		Number Inundated			Percent of Total Inundated		
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	143	16	31	37	11%	22%	26%
New Castle	80	16	30	36	20%	38%	45%
Kent	19	0	1	1	0%	5%	5%
Sussex	44	0	0	0	0%	0%	0%

Source: DNREC, Salvage Yards GIS Layer, 2010-10-27

Potential Economic Impact: In some cases for operating landfills, engineering controls could be put in place to minimize or prevent impacts attributed to sea level rise. Installation and ongoing operation of engineering controls would be an additional cost to the landfill operators. This could lead to higher tipping fees at operating commercial or DSWA landfills, and shortfalls in post-closure financial assurance at closed landfills. Sea level rise may also reduce the safe holding capacity of certain sites leading to the need for acquisition of additional disposal sites. If a site is potentially exposed and engineering measures are not cost effective, the waste from these disposal aresult need to be removed and relocated to inland landfills, salvage yards, or recycled. The cost of relocation would range from thousands of dollars, to many millions depending upon the size of the site (Cwith of Australia, 2009). Additionally, some closed landfill and salvage yard sites may have been owned or operated by municipalities or counties. Increased remedial or maintenance costs at these facilities will potentially add to the tax burden on residente.

Potential Social Impact: Many local landfills and salvage yards are located in places that were undesirable or not suitable for the then-recognized community needs and were cheap to procure. As a result, many older sites were placed in or adjoining flood prone and low-lying lands, including wetlands and subaqueous lands. A changed functionality of landfills or salvage yards due to sea level rise may impact the health and safety of local residents with release of waste material. Also, increased tipping fees and construction of new sites could increase rates for residents which tend to promote increases in illegal dumping.

Potential Environmental Impact: Inundation of a landfill or a salvage yard can result as sea levels rise. A ponding effect may cause increased leachate (liquid that moves through or drains from a landfill) production by adding water to the volume of wastes in the landfill or salvage yard and causing varying degrees of saturation (which may affect structural stability). Waste solution due to floodwater may result in increased leachate production and the potential migration of these wastes onto neighboring properties. Active sites that are not capped are particularly vulnerable (Flynn, Walesh, Titus, & Barth, 1984).

Waves can cause extensive erosion of any loose cover material. Erosion is particularly significant at landfills constructed so that the waste is above ground level. Salt water intrusion from sea level rise may affect landfills with clay caps and/or liners. In coastal areas, where the extent of saltwater intrusion inland may be significant, it is common to have shallow unconfined aquifers with depths that respond rapidly to fluctuations in sea level. Changing water tables could threaten wastes stored in surface impoundments, landfills, and salvage yards. Furthermore, saltwater can permeate clay liners that are impervious to freshwater. As a result, the risk of wastes leaching through the liners would increase (Flynn, Walesh, Titus, & Barth, 1984).

It is difficult to specify the types of materials disposed into landfills and salvage yards or the quantity that may be released back into the environment by sea level rise. Most disposal sites contain quantities of petroleum products, demolition waste, asbestos, pesticides, plastics, and heavy metals fixed into the soil/waste matrix (Cwith of Australia, 2009). If these materials were released back into the environment it would constitute a significant environmental hazard. However, the potential for increased release of contaminants is site-specific and requires evaluation of each facility individually.

### DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites

The DNREC Site Investigation and Restoration Section (SIRS) is responsible for the identification, evaluation, and remediation of sites within the state that have had releases of hazardous substances. A hazardous substance, as defined by the Delaware Hazardous Substance Cleanup Act and Federal Regulations, is any compound that presents a risk to the public health, welfare, or the environment.

A hazardous substance may be a solid, liquid, or gas, and may be radioactive, flammable, explosive, toxic, or corrosive. Hazardous substances also include substances that can be biohazards, oxidizers, or irritants.

A SIRS site is any location which has been identified by DNREC Site Investigation and Remediation Section where a hazardous substance has or may have been released that can have the potential to harm humans, animals, or the environment. Sites vary in origin, size, and the toxicity and bioavailability of the contaminants present. Accordingly, the hazard levels posed by unremediated sites also vary widely. In order to protect the public from the potential environmental and health results of hazardous substances, government agencies at all levels are required to expend resources on moving, mitigating, or protecting these sites.

The major impacts of sea level rise on SIRS sites are erosion, inundation, waste solution (leachate) migration, saltwater intrusion, and in the worst cases, potential damage to remedial structures, e.g., dikes, bulkheads, caps, liners, and leachate control systems through erosion, flooding, or wave action. Sites may initially be subject to intermittent flooding from lunar high tides, which may cause an increased rate of release of contaminants. As sea levels continue to rise, inundation will become more chronic and saltwater intrusion of groundwater may occur increasing the potential for waste solution migration.

Exposure to Sea Level Rise: Exposure of SIRS sites to future sea level rise was assessed by using GIS point and polygon layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of SIRS sites throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will be able to function. To fully assess the impact sea level rise will have on SIRS sites, additional criteria will be needed including; surrounding soil type; site construction including liner and cap material; remediation status and methods; contaminants present at the site; materials stored on-site; and groundwater hydrology.

Statewide, approximately 39% of SIRS sites are within the 1.0 meter sea level rise scenario (Table 73) which comes to a total of nearly 30,200 acres that are potentially exposed (Table 72). In New Castle County, 285 SIRS sites are within the 1.5 meter scenario (Table 73), however only 27% of the total acreage of SIRS sites will be potentially exposed to sea level rise. Kent County is projected to have the greatest amount of acreage impacted with approximately 67% - 80% acres exposed (Table 72) on 16 – 21 SIRS sites. Fifty sites in Sussex County are within the 1.5 meter scenario with 5,827 acres potentially inundated by sea level rise. See Map Appendix for man.

Table 72 - Acres of SIRS Sites Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated			
	rotal Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	60,088	24,586	30,202	32,669	41%	50%	54%	
New Castle	20,148	3,021	4,487	5,487	15%	22%	27%	
Kent	26,816	17,909	20,750	21,356	67%	77%	80%	
Sussex	13,125	3,656	4,966	5,827	28%	38%	44%	

Table 73 - Number of SIRS Sites Exposed to Sea Level Rise

Ct-	Total Number	Number Inundated			Percent	of Total Inu	ndated
County	total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	785	262	308	345	33%	39%	44%
New Castle	543	213	252	285	39%	46%	52%
Kent	103	16	20	21	16%	19%	20%
Sussex	139	41	45	50	29%	32%	36%

Source: DNREC - SIRS Investigation and Remediation Database, unpublished.

Potential Economic Impact: Reduced functionality of remedial measures DNREC SIRS Contaminated Sites may increase the remediation costs and influence the type of practices that are viable. If sea level rise changes the functionality of these sites, any redevelopment and the related income that would be produced may be unobtainable, thereby affecting tax revenues for coastal towns. If a site is potentially exposed and engineering measures are not cost effective, the waste and contaminants from these sites will need to be removed and relocated inland adding to the cleanup and maintenance costs.

Potential Social Impact: Socially, inundation of DNREC SIRS Contaminated Sites may threaten the health and safety of the neighboring public due to the release of hazardous substances. Without the opportunity to redevelop, these sites will remain unusable and unproductive, possibly raising concerns about poverty, health, crime, and urban sprawl in communities subject to sea level rise. Many SIRS sites are near or adjacent to low-income communities. Sea level rise may make site cleanup more expensive, less feasible, or impair the ability to control contamination in the community, representing a significant social and environmental justice issue.

Potential Environmental Impact: Environmentally, inundation or saltwater intrusion of DNREC SIRS contaminated sites may affect surrounding areas by increasing the potential for movement of hazardous substances. This may also have an influence on the effectiveness of current remedial practices. Some remediation sites incorporate or are associated with constructed wetlands, re-vegetated areas, or other mitigation/restoration projects. The usefulness of these projects will likely be impaired or lost along with their environmental benefits if sites are inundated or even occasionally exposed to flooding.

Increased risk from storms is an important factor on SIRS sites. A rise in sea level would bring new sites into floodplains and result in more severe flood levels for those already in floodplains. Furthermore, the risks from damaging waves would increase as deeper water will allow these waves to penetrate further inland (Flynn, Walesh, Titus, & Barth, 1984).

In a SIRS site, water is most often the media that displaces hazardous substances. Since saltwater is heavier than freshwater, it has a greater potential to displace contaminated groundwater plumes, pushing wastes upward to ground level. Sea level rise, especially saltwater intrusion, will increase this factor. Depending on the geological characteristics of a site, the direction of plume migration may be difficult to predict without a comprehensive geophysical analysis (Barnett, 2010).

### Underground Storage Tanks (UST) & Leaking Underground Storage Tanks (LUST)

Underground storage tanks (UST) systems are tanks including connected underground pipes, which are used to contain an accumulation of regulated substances, and the volume is 10% or more beneath the surface of the ground. Septic tanks, regulated pipelines, surface impoundments, storm or waste water collection systems, and tanks in an underground area such as a basement are not included as an UST. A UST facility may consist of a property containing one or more USTs.

Leaking underground storage tanks (LUST) are underground storage tanks that have had a confirmed release of a regulated substance to the environment. Typically if a LUST is found, the Delaware Department of Natural Resources and Environmental Control requires the owner/operator to remove the tank and then holds the responsible parties accountable for performing further corrective actions. Once a release has been confirmed the DNREC Tank Management Section refers to the property as a LUST site. It is important to note that the same property can have multiple confirmed releases that require a cleanup over several years.

UST facilities and LUST sites that lie in the path of sea level rise may be adversely affected. Sites may initially be subject to intermittent flooding from lunar high tides resulting in the corrosion of tanks and the movement of leaking contaminants. This may cause short-term functionality problems as well as flood damage if sites are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

It is worth noting that UST regulation excludes smaller tanks such as those used for residences. It has not been determined how many home fuel oil or propane USTs may exist in the state and in what areas. Because residential USTs are not regulated, these tanks may be less rigorously maintained and inspected than regulated USTs and may actually have a higher rate of deterioration or failure.

Exposure to Sea Level Rise: Exposure of UST facilities and LUST sites to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of UST facilities and LUST sites throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether an underground storage tank facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will sable to function. To fully assess the impact sea level rise will have on UST facilities and LUST sites, additional criteria will be needed including: material stored in tank; volume of tank and pipes; construction of tank and pipes; connecting pipe network; surrounding soil type; floatation potential of tank and pipes; and groundwater elevations to determine pre-inundation effects. Moreover, UST sites in coastal or other low-lying areas may already be in contact with groundwater. If groundwater rises due to SLR, USTs could be affected by saltwater intrusion even if the site surface is not inundated.

Statewide, approximately 6% of UST facilities are within the 1.5 meter sea level rise scenario (Table 74). In New Castle and Kent County, nearly 3% of each county's UST facilities will be potentially exposed to sea level rise at the 1.0 meter scenario. Sussex County is projected to have the greatest number of tanks impacted with approximately 3%–11% of the county's UST facilities being exposed to sea level rise. See Map Appendix for man.

Table 74 - Number of UST Facilities Exposed to Sea Level Rise

	Tatal Number	Number Inundated			Percent of Total Inundated			
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m	
State	3601	65	145	208	2%	4%	6%	
New Castle	2107	29	58	94	1%	3%	4%	
Kent	639	9	16	17	1%	3%	3%	
Sussex	855	27	71	97	3%	8%	11%	

Source: DNREC Underground Storage Tanks, 2010-10-27.

Statewide, approximately 2% of LUST sites are within the 1.0 meter sea level rise scenario (Table 75). In all three counties, nearly 5% of LUST sites will be potentially exposed at the 1.5 meter scenario. Sussex County will not see any potential impacts until the 1.5 meter scenario. In New Castle County, potential exposure to sea level rise will occur at the 1.0 meter scenario while Kent County LUST sites will potentially be impacted at the 0.5 meter scenario. See Map Appendix for map.

Table 75 - Number of LUST Sites Exposed to Sea Level Rise

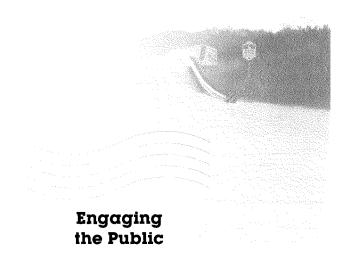
	Tatal Number	Number Inundated			Percent	ndated	
County	Total Number	0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	166	2	3	8	1%	2%	5%
New Castle	61	0	1	3	0%	2%	5%
Kent	42	2	2	2	5%	5%	5%
Sussex	63	0	0	3	0%	0%	5%

Source: DNREC, Leaking Underground Storage Tanks, 2010-11-15.

Potential Economic Impact: Reduced function or increased rate of deterioration of underground storage tanks, resulting from sea level rise, may impact operating costs of facilities. Certain industries that are heavily dependent on underground storage tanks, such as gas stations, may have costly repairs or have to close or move operations. This would cause a loss of income for the facility owners. Concerning leaking underground storage tanks, sea level rise may allow contaminants to migrate from the surrounding soil to water resources increasing the cost and scope of site remediation.

Potential Social Impact: Socially, changed functionality of underground storage tanks may impact the views and safety of neighboring properties by requiring surface placement of tanks. If sea level rise allows contaminants from leaking tanks to spread into surrounding areas, health and environmental impacts may also occur. Local communities may see a drop in property desirability due to contamination risk which would impact property values.

Potential Environmental Impact: Concerning the environment, underground storage tank facilities would have the options of either developing emergency plans to remove contents prior to flooding from sea level rise or incorporating structural engineering solutions. But, if these measures failed, the consequences could be serious. Tanks could overflow, containers could float or spill if not properly secured, structural damage to above-ground or partially above-ground tanks could be caused by floating debris or by increased hydrostatic pressure, and saltwater could corrode tanks and containers (Flynn, Walesh, Titus, & Barth, 1994). Spills, structural damage, and corrosion would increase the risk of soil and water contamination. Surrounding natural habitats would be exposed to hazardous substances causing harm to the local wildlife and plant community.



### **Engaging the Public**

Transparency and public involvement is important to the members of Sea Level Rise Advisory Committee. All Advisory Committee Meetings are posted to the State Meeting Calendar, are open to the public and time is reserved during each meeting for public comment. In addition, meeting agendas, meeting summaries, handouts, and presentations are publically accessible on the committee website at http://de.gov/slradvisorycommittee.

In order to obtain initial feedback on the work of the committee and its preliminary findings, a series of public engagement sessions was held during the month of November 2011. These sessions were held in the late afternoon through early evening to attempt to accommodate the schedules of as many interested citizens as possible. Engagement sessions were held at the following locations:

November 9: Middletown High School, Middletown

November 15: Georgetown Public Library, Georgetown November 17: William Penn High School, New Castle

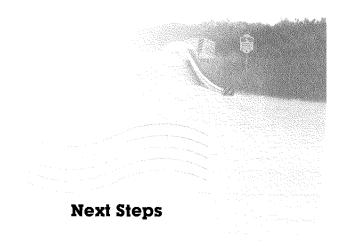
November 21: Kent County Administration Building, Dover November 29: Cape Henlopen High School, Lewes

The engagement sessions were designed to be participatory and interactive. Sea Level Rise Advisory Committee members and Delaware Coastal Programs staff manned six different displays where participants could learn about sea level rise, its potential effects on Delaware and view maps of sea level rise inundation areas. An overview presentation was also given twice during each session. Participants provided feedback directly to advisory committee and staff members and/or filled out comment forms that asked participants the following questions:

For persons unable to attend in person, meeting display boards, presentations, and comment forms were available online on the Advisory Committee's website at http://de.gov/sfradvisorycommittee. A total of 196 persons attended the five public engagement sessions. Forty-four comment forms were received. Comments received during this process were compiled for use by the Advisory Committee in the vulnerability assessment and are available in Appendix E.

In addition to these efforts, Delaware Coastal Programs staff, have made themselves available for presentations to community groups about sea level rise, its effects, and the work of the Sea Level Rise Committee. More than a dozen such presentations were given during 2011 to a variety of audiences statewide, providing additional opportunities for citizens to become aware and involved with the work of the Advisory Committee.

The Sea Level Rise Advisory Committee will continue to work to engage the public in its decision-making process



### **Next Steps**

The Sea Level Rise Vulnerability Assessment will be used by SLRAC and workgroup members to prioritize and inform the development of adaptation strategies. It may also be used to identify resources or geographic areas for which more in-depth, site-specific vulnerability assessments should be conducted.

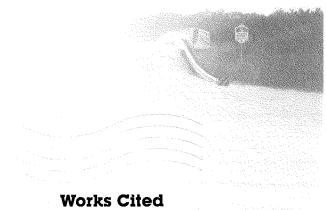
Phase II of this project will develop an adaptation plan for the state. Adaptation is a term used to refer to any action that decreases vulnerability to new or emerging conditions, like sea level rise. There are three primary mechanisms for sea level rise adaptation: Protection; accommodation and retreat.

Protection strategies are actions that would keep rising water out of a specific area. Examples include construction of sea-walls, building up dunes and beaches through beach replenishment projects and shoreline armoring among others.

Accommodation strategies are actions that allow continued use of an area or structure without shoreline structures. Examples include drainage improvement projects, raising buildings on pilings and flood-proofing. Accommodation can also include changes in behavior like evacuating early from flood prone areas and changing driving patterns to avoid frequently flooded roadways.

Retreat strategies are actions that plan for the eventual removal of structures and uses from an area that will be subject to inundation from sea level rise. Examples include relocation of infrastructure and flood prone buildings inland, purchase of land or conservation easements in at-risk areas and siting new structures outside of vulnerable areas.

In order to employ any of these strategies, existing programs, plans, policies and funding mechanisms in the state must be investigated for their ability to support adaptation actions. Policy and funding gaps that could hinder adaptation must also be identified. The SLRAC will conduct this assessment with the assistance of subject matter experts and make recommendations for improvements. The SLRAC will not oversee the implementation of recommendations, however it is envisioned that a committed group will coordinate to obtain funding, resources and support to implement recommendations over several years.



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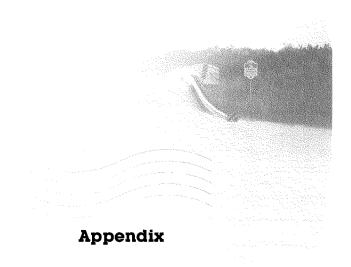
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### A - Acronyms

- CZA Coastal Zone Act
- DFS Delaware Forestry Service
- DNREC Delaware Department of Natural Resources and Environmental Control
- DCP Delaware Coastal Programs
- DelDOT Delaware Department of Transportation
- DRBC Delaware River Basin Commission
- DSWA Delaware Solid Waste Authority
- EPA United States Environmental Protection Agency
- FEMA -- Federal Emergency Management Agency
- GIS Geographic Information Systems
- HCC Habitats of Conservation Concern
- HSIP Homeland Security Infrastructure Protection
- IMPLAN Impacts Analysis for Planning
- IPCC Intergovernmental Panel on Climate Change
- LiDAR Light Detection and Ranging
- LMSL Local Mean Sea Level
- LUST -- Leaking Underground Storage Tank
- MHHW Mean Higher High Water
- NFIP National Flood Insurance Program
- NOAA National Oceanic and Atmospheric Administration
- NWR National Wildlife Refuge
- PDE Partnership for the Delaware Estuary
- SIRS Site Investigation & Remediation Section
- SLAMM Sea Level Affecting Mashes Model
- SLR Sea Level Rise
- SLRAC Sea Level Rise Advisory Committee
- SoVI Social Vulnerability Index
- UD -- University of Delaware
- USDA United States Department of Agriculture
- USFWS United States Fish & Wildlife Service
- USGS United States Geologic Survey
- UST Underground Storage Tank
- WILMAPCO Wilmington Planning Area Council

### B - Glossary

Adaptation – An action that can be taken to adjust to new or emerging conditions. With respect to sea level rise, adaptation can include a variety of actions including raising structures, building sea walls, restoring natural areas, relocating structures and avoiding investments in high risk areas.

Anadromous Fish – A fish species that is born in fresh water, spends most of its life in the ocean, and returns to fresh water to spawn. Examples would be salmon, striped bas, and sturgeon.

Bathtub Model – A water surface model that floods all land below a certain elevation, unless there is a structure that would block the tidal flow.

Biodiversity – The number and variety of organisms found within a specified geographic region.

Brownfield – Any vacant, abandoned, or underutilized real property the development or redevelopment of which is hindered by the reasonably held belief that the property may be environmentally contaminated.

Chronic – Persisting for a long time or constantly recurring.

Coastal Impoundment – A topographic depression, excavation, or diked area, primarily formed from earther materials and designed to hold accumulated water and provide storm water control.

Conservation Easement – Legal agreement between a landowner and a land trust (or other organization) which places protective environmental restrictions on the property.

Corrosion – The gradual destruction of a material, usually metal, by a chemical reaction with the surrounding environment.

Domestic Well – A privately owned well that supplies groundwater for human consumption and other household uses.

Effluent – Liquid waste or sewage discharged into surface water or groundwater.

Environmental Justice – The fair treatment and meaningful involvement of people from all races, cultures, and incomes regarding the development of environmental laws, regulations, and policies.

Estuary – A partly enclosed coastal body of water with one or more rivers or streams flowing into it with a free connection to the open sea. Estuaries form a transition zone between river environments and ocean environments and are subject to both marine influences and riverine influences.

Eustatic Sea Level Rate – The worldwide change of sea level elevation with time. The changes are due to such causes as glacial melting or formation, thermal expansion or contraction of sea water, etc.

Exposure – Refers to the presence of people, livelihoods, environmental resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by sea level rise and which, thereby, are subject to potential future harm, loss, or damage.

Farmland of Statewide Importance – Land other than prime farmland with a good combination of physical and chemical characteristics for crop production.

### **B** - Glossary

Feeder Road – A secondary road used to bring traffic to a major road or highway.

Functionality – Determines whether a resource can continue to meet its intended purpose.

Future Development Areas – Lands within the long-term growth plans (greater than five years) of county and municipal governments and/or are adjacent to already developed or developing areas.

Geographic Information System – A system of hardware and software used for the storage, retrieval, mapping, and analysis of geographic data.

Geomorphology – The scientific study of landforms and the processes that shape them.

Groundwater Recharge Area – The area where an aquifer is replenished from natural processes, such as the infiltration of rainfall and snowmelt or from human interventions, such as the use of storm water management systems.

Habitats of Conservation Concern – Types of environments (habitats) identified in the Delaware Wildlife Action Plan that are rare, sensitive to disturbance, have a high density of rare plants, or have special significance to the state.

Hydraulic – denoting a liquid moving in a confined space under pressure.

Hydrogeology/ Hydrogeological – Branch of geology that deals with the occurrence, distribution, and effect of groundwater.

Hydrology/Hydrological – Properties, distribution, and effects of water on the earth's surface, in the soil, and the atmosphere.

Local Mean Sea Level – The height of the ocean relative to land, measured hourly and averaged over a nineteen year period known as the National Tidal Datum Epoch.

Intermittent - Occurring at irregular intervals.

inundation – Movement of coastal water over land as a result of sea level rise.

LIDAR (Light Detection and Ranging) – An optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser.

Land Subsidence – The lowering of a portion of the earth's crust.

Mean Higher High Water – The long-term average of the higher of the daily high tides.

Mean Sea Level – The average level of the sea observed over a period of time and referenced to a water or land elevation benchmark. Tide gauges are frequently used to measure sea level.

Non-point Source Pollution – Pollution source that is not fixed or specific. Instead the source is mobile or widely scattered.

Preservation District – A voluntary agreement to use land only for agricultural purposes for at least a ten year period.

Prime Farmland – Land with the optimal combination of physical and chemical characteristics for crop production.

Public Well – A privately or publicly owned well that provides water to a public water system including. (1) community water systems, such as municipalities, mobile home parks, or nursing homes; (2) transient non-community water systems, such as campgrounds, motels, and gasoline stations; and (3) non-transient, non-community systems, such as schools, factories, and hospitals.

Remediation - The removal of pollution or contaminants from environmental media such as soil, groundwater, sediment, or surface water for the general protection of human health and the environment.

Saltwater Intrusion – Occurs in coastal freshwater aquifers when the different densities of both the saltwater and freshwater allow the ocean water to intrude into the freshwater aquifer due to its greater density. Sea Level – The level of the sea after averaging out short-term variations due to wind and waves.

Sea Level Rise – long-term increases of mean sea level. At a coastal site, sea level rise can occur both as a consequence of worldwide increases in sea level due to an increased volume of water in the oceans and due to local sinking of land surfaces.

Social Vulnerability – The inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed. A person's vulnerability to environmental hazards is determined by access to resources, diversity of income sources, and by the economic status of the person or household.

Storm Surge – The local change in the elevation of the ocean along a shore due to high winds and low atmospheric pressure experienced during a storm. The storm surge is measured by subtracting the astronomic tidal elevation from the total elevation. Storm surge can be potentially catastrophic, especially on low lying coasts with gently sloping offshore topography.

Tidal Prism – The difference between the mean high water volume and the mean low water volume in an estuary.

Tide Gauge – A water measurement device used to continuously record coastal sea level and referenced to an elevation benchmark.

Vulnerability – Susceptibility of a resource to negative impacts from sea level rise.

Wellhead – The principal source of a well or stream.

Wellhead Protection Area – The surface and subsurface area surrounding a water well or well-field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water wells or well-fields.

## C - Advisory Committee and Workgroup Members

#### Sea Level Rise Advisory Committee Members Sarah Cooksey ...... Delaware Department of Natural Resources and Environmental Control ......Positive Growth Alliance Richard Collins .....Tidewater Utilities, Inc. Gerard Esposito..... ......Delaware League of Local Governments/City of Lewes Alt: Victor Letonoff Delaware Nature Society Alternate: Chris Bason Center for the Inland Bays Mary Ellen Gray...... Kent County Department of Planning Services ...... Delaware Office of the Governor Constance Holland ..... Roger Jones ..... .....The Nature Conservancy Alternate: Jen Adkins Partnership for the Delaware Estuary Alternate: Rob McCleary Bill Lucks ..... ...... Delaware Association of Realtors Keith Rudy ..... .... Home Builder's Association of Delaware Kurt Reuther ...... Delaware Department of Safety and Homeland Security Alternate: Don Knox Jeff Shockley ..... John Taylor ...... Pam Thornburg-Bakerian ......Delaware Farm Bureau Chad Tolman . Delaware League of Women Voters Alternate: Peggy Schultz Society & Economy Workgroup Members David Arnes UD Center for Historic Architecture and Design Rich Collins Positive Growth Alliance Mark Davis ... ......Delaware Department of Agriculture Barbara DeHaven Andrea Godfrey Delaware Economic Development Office The Honorable Quinn Johnson ...... Delaware House of Representatives Karl Kalbacher ..... New Castle County Sarah Keifer ...... Kent County Department of Planning Michael Kirkpatrick .....Delaware Department of Transportation

Society & Economy Wo	rkgroup Members
Bill Lucks	
Rob McCleary	Delaware Department of Transportation
Richard Perkins	Delaware Department of Health and Social Services
Mike Powell	
Keith Rudy	
John Taylor	Delaware State Chamber of Commerce
Greg Williams	
Public Safety & Infrastri	ucture
Dave Carlson	Delaware Emergency Management Agency
Greg DeCowsky	
Jerry Esposito	
John Greer	Public
Karissa Hendershot	
Jim Kirkbride	Public
Michael Kirkpatrick	Delaware Department of Transportation
Don Knox	Delaware Emergency Management Agency
Nancy Lawson	Public
John Laznik	
Victor Letonoff	
Robert McCleary	Delaware Department of Transportation
Cindy Miller	Public
Peggy Schultz	League of Women Voters
Dr. Chad Toiman	League of Women Voters
Natural Resources	
Jennifer Adkins	Partnership for the Delaware Estuary
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Sarah Cooksey	Delaware Department of Natural Resources and Environmental Control
Morgan Ellis	Delaware Department of Natural Resources and Environmental Control
Brenna Goggin	
Susan Guiteras	
Roger Jones	
Kevin Kalasz	Delaware Department of Natural Resources and Environmental Control
Andy Manus	
Chris Sommerfield	
Hillary Stevens	University of Delaware
Michael Stroeh	U.S. fish and Wildlife Service
Pam Thornburg-Bakerian	Delaware Farm Bureau
Dahin Tulor	Delaware Department of Natural Resources and Environmental Control

Workgroup Public Safety and Requesting Data				
Infrastructure Layers Used in Analysis	PS&I	S&E	NR	Source Notes
Schools (K-16)	x			Del. Dept. of Education, Delaware Public School Layer, 9-29-2010
Fire and Rescue stations	x	х		TechniGraphics, Inc., Delaware Fire Stations 2008 Q1, 2008-04-02
Police stations	x	x		Department of Homeland Security (Technigraphics), Delaware Law Enforcement 2009 Q4, 20091218
Communication/cell towers	х	х		FCC, Cellular Tower Locations , 20030427
Roads	х	x		Del. Dept. of Transportation, Road Centerline File, 2008-06-01
Bridges	х	х		Del. Dept. of Transportation, Road Centerline File, 2008-06-01
Bus Routes	х			Del. Dept. of Transportation - DART, DTC TRAPESE Routes and Stops, 20101001
Airports	x			HSIP Freedom (Department of Homeland Security); Del. Dept. of Transportation - Aviation
Railroads - Stations/Lines/Holding areas	x			USGS, 7.5 minute Digital Line Graphs - Rail, 20100930; HSIP Freedom (Department of Homeland Security)
Ports and Ferry Terminals	x	x		DNREC - Office of the Secretary, Coastal Zone Heavy Industries, unpublished.
Sewer pump stations	х	х	x	Kent County Engineering, New Castle County Special Services and Sussex County GIS
Sewer lines	х	x	x	Kent County Engineering, New Castle County Special Services and Sussex County GIS
Waste Water Facilities	x	x	x	DNREC - Financial Assistance Branch (TetraTech), POWWTP, 1/11/2010 Kent County Engineering, New Castle County Special Services and Sussex County GIS
Septic Systems	х	х	х	DNREC, Delaware Septic Systems (last update 20101123), unpublished
Hospitals and medical facilities	x	x-		DE Div. of Public Health (UofD - CADSR), Delaware Hospitals, 2011-05-31
Emergency Operation Centers	x	x		Delaware Emergency Management Agency, EOC shapefile, 2011-04-03 [edit by Delaware Coastal Programs]

Public Safety and		orkgroi esting	agterner garerier i segretier	
Infrastructure Layers Used in Analysis	PS&I	S&E	NR	Source Notes
Evacuation Routes	x			Del. Dept. of Transportation Traffic Management Team (Edwards and Kelcey), 2007 Evacuation Routes, 2010-15-04
Pipelines	x			DOT-PHMSA-National Pipeline management System
Wells - domestic, public, irrigation, industrial	x	x		DNREC-Water Resources-Doug Rambo
Navigation Aids	x			HSIP Freedom (Department of Homeland Security)
Correctional Facilities	x			TechniGraphics, Inc., Delaware Correctional Institutions 2007 Q4, 2007-11-05
Day Care centers	x			UofD - CADSR, Current Day Care Centers, unpublished.
Senior Centers	х			Del. Div. of Public Health (UofD - CADSR)
Nursing Homes	х			Del. Div. of Public Health (UofD - CADSR)
Refineries	x	x		DNREC - Office of the Secretary, Coastal Zone Heavy Industrial Facilities (20110321), unpublished.
Factories	х	х		EPA, EPA Facilities Toxics Release Inventory, 20080212
Site Investigation and Restoration Section (superfund, HSCA)	х	x		DNREC - 5IRS, Site Investigation and Remediation Database, unpublished.
Leaking Underground Storage Tanks	x			DNREC, Leaking Underground Storage Tanks, 2010-11-15
Underground Storage Tanks	х			DNREC, Underground Storage Tanks, 2010- 10-27
Brownfields	x			DNREC, Brownfields GIS Layer, 2010-10-27
Salvage Yards	х			DNREC, Salvage Yards GIS Layer, 2010-10-27
Hazardous Waste Generator	х			DNREC, Hazardous Waste Generator GIS layer, 2010-11-16

Public Safety and Workgroup Infrastructure Layers Requesting Data				
Requested but not Used in Analysis	PS&I	S&E	NR	Source Notes
Emergency Shelters	×			Data unavailable for Public Use
Public Utilities	х	x		Unspecific request. Several specific utility data layers collected and listed elsewhere
Private Utilities	х	х		Unspecific request. Several specific utility data layers collected and listed elsewhere
Wind Generation	х			Data unavailable for Public Use
Combined Sewer Overflows	х			Data Incomplete
Spray irrigation fields	х			Data Unavailable in GIS format
Community treatment facilities	х			Data unavailable for public use
Telephone switching stations	х			Data unavailable for public use
Water Supply Intakes	x			Data unavailable for public use
DelDOT Maintenance Yards	х			Data Incomplete
School Bus Storage	х			Data Unavailable in GIS format
Emergency Shelters	х			Data unavailable for Public Use
Public Utilities	х	х		Unspecific request. Several specific utility data layers collected and listed elsewhere
Private Utilities	х	х		Unspecific request. Several specific utility data layers collected and listed elsewhere
Wind Generation	х			Data unavailable for Public Use
Combined Sewer Overflows	х			Data Incomplete

	Workgroup Requesting Data			
Society & Economy Layers Used in Assessment	PS&I	S&E	NR	Source Notes
Social Vulnerability Index		x	***	NOAA Coastal Services Center (2000 Census)
Housing Units -Housing Units in mobile homes, trailers, others		х		UD CADSR - 911 Addressing
Income - Median Household and Per Capita		х		2010 Census (UofD - CADSR)
Delaware Environmental Justice Communities		х		WILMAPCO (2000 Census)
Heavy Industrial Sites		х		DNREC-Coastal Zone Act permitted sites; DNREC Toxic Release Inventory
Land use/land cover		х		datamil.delaware.gov
Agriculture Preservation/Easements		x	х	Del. Dept. of Agriculture, State Ag Easements, 2010-09-17
State Planning Investment Layers		x	x	Delaware OSPC, Investment Levels, Delaware State Strategies for State Policies and Spending (2010), 2010-10-01
Historic and Cultural resources			x	Delaware State Historic Preservation Office, CRS Inventory, unpublished, and National Register Properties, SHPO
Residential Addresses		х		UD CADSR - 911 Addressing
Inundated State Landmass		х		USGS and Delaware Geologic Survey, State Outline (Area), 2007-04-01
Tourist Destinations	х	x		DNREC Facilities-parks, beaches - DE Division of Parks and Recreation
Commercial Buildings		х		County 911 Databases [digitized by UofD - CADSR]
Agriculture Data - acreage and crop/animal types and economic impact		x	x	Del. Dept. of Agriculture, Ed Ratledge-UD, DEDO, Conservation districts Productive Soils data from USDA, LandUse/LandCover
Agriculture facilities/infrastructure		x	х	Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05- 19
Business Licenses		х		Delaware Division of Revenue, through University of Delaware CADSR

Society & Economy Layers	Workgroup Requesting Data			
Requested but not Used in Assessment	PS&I	S&E	NR	Source Notes
Date structure was built		x		Data unavailable
Tax Ditches		х		Data available but later deemed not necessary for inclusion
Impermeable Surfaces		х	х	OSPC-OMB, 2007 Impervious Surface Data, 2008-05-18
Zoning		х		Statewide data not available.
Water Franchises		х		Data requested by later deemed not necessary for inclusion
Special Overlay Zones		х		Data requested by later deemed not necessary for inclusion
Floodplains		х		Not 'at-risk' per se. Information more suited to adaptation.
Maps where insurance is available		Х		Data requested by later deemed not necessary for inclusion
Recurring Damage Claims		х	-	Data unavailable statewide
Rating Schedules		х		Data requested by later deemed not necessary for inclusion
"Pre-FIRM" maps		х		Data requested by later deemed not necessary for inclusion
Affordable Housing communities		х		Data unavailable statewide
Senior Housing		X		Data unavailable statewide
Manure Sheds		х		Data unavailable statewide
Buffer Regulations		х		Data unavailable statewide
Large Employers		х		Data requires analysis beyond scope of current project

	Workgr Requestin		
Natural Resources Layers Used in Assessment	PS&I S&E	NR	Source Notes
Wetlands		x	DNREC, De_Wetlands_20100901_PD6, 2010- 09-01
State Protected Areas		х	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Recharge Areas		х	DNREC, Recharge Areas, 2010-10-27
Wellhead Protection Areas		х	Sources: DNREC, Statewide WHPA 2009, 2009-09-29
Natural Areas	1000	х	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Habitats of Conservation Concern		х	DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished
Nature Preserves		х	DNREC Division of Parks and Recreation, Nature Preserves (2008), unpublished
Coastal Impoundments		х	Delaware Coastal Programs, Impoundments (2010), unpublished
Public Access Sites (ORI2009)		x	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Conservation Easements		х	DNREC Division of Parks and Recreation, Conservation Easements (2010), unpublished
Forests		x	Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05- 19
DNERR		х	Delaware Coastal Programs, DNERR Boundary (2010), unpublished
Wetlands		х	DNREC, De_Wetlands_20100901_PD6, 2010- 09-01
State Protected Areas		x	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Recharge Areas		х	DNREC, Recharge Areas, 2010-10-27
Wellhead Protection Areas		x	Sources: DNREC, Statewide WHPA 2009, 2009-09-29

Natural Resources Layers	Workgroup Requesting Data				
Requested but not Used in Assessment	PS&I	S&E	NR	Source Notes	
Depth to Water Table			х	Data requires analysis beyond scope of current project	
Stormwater Management Structures			х	Data unavailable in GIS format	
Salt Line/Salt water intrusion		х	х	Data requires analysis beyond scope of current project	
Turbidity, nutrient changes, salinity			х	Data requires analysis beyond scope of current project	
Head of tide			x	Data unavailable	
Increased Extent of storm surges and habitat changes			х	Data requires analysis beyond scope of current project	
Fisheries, EFH, nursery habitat			x	Data not at scale suitable for vulnerability assessment	
Shellfish maps			x	Data requires analysis beyond scope of current project	
Freshwater mussels			x	Data unavailable in GIS format	
Site Specific species migration studies			х	Data requires analysis beyond scope of current project	
Map physical barriers to wetland migration			x	Data requires analysis beyond scope of current project	
Marsh Vulnerability Index			х	Data requires analysis beyond scope of current project	
Model marsh response to SLR			x	Data requires analysis beyond scope of current project	
Wetland to Forest migration maps from The Nature Conservancy			х	Data requires analysis beyond scope of current project	
Economic Value of hunting and fishing			x	Data requires analysis beyond scope of current project	
Depth to Water Table			х	Data requires analysis beyond scope of current project	

The Delaware Sea Level Rise Advisory Committee hosted a series of five public engagement sessions in November 2012, as described in the Public Engagement Section. All comments received in writing or by phone in response to these sessions are below:

Do you have concerns about sea level rise not mentioned today that you would like the sea level rise advisory committee to consider? Please describe.

- Should have a chart that draws a month by month continuous curve of tide gauge data.
- Yes, the actual impacts on homes in the vulnerable areas. For instance, South Bethany is greatly affected by 0.5 meter SLR. Can we project when these areas are going to be impacted to the point that the homes will be unusable?
- This information needs to be shared with the local coastal communities in Sussex County so that they can
  plan their new construction projects with this information in mind. I believe that future construction should be
  severely restricted along the coast.
- It would be helpful to describe: (a) impacts of SLR on those living in high elevations (b) Delaware's SLR efforts vs. those of surrounding states, USA, global.
- Impacts on underground utilities and water supply.
- Require the deed or lease to describe possibility of flooding and make the realtor liable if they do not show it
  to the customer. Deny federal flood insurance to properties that flood repeatedly. Stop beach replenishment
  which is a waste of taxpayer money. At Fowlers Beach the replenished beach lasted only a month. Avoid
  waivers for waterfront lots. Bulkheads do not work well. Levees also have problems.
- More community outreach efforts target city and town councils.
- No, DNREC is getting too powerful and is infringing on private citizens rights.
- I am not concerned at all about sea level rise.
- Impact of increased salinity on oysters?
- Impact at local levels/ municipalities
- No, covered well and everything was explained in detail. Everyone took time to answer questions about localized areas of concern. Good presentation and exhibits. Thank you.
- Pollutant transfer particularly from contaminated areas. This was alluded to in the presentation but should be addressed more specifically and would help underscore the public health impacts of SLR.
- I believe the projections concerning sea level rise may not be accurate. Temperatures have fluctuated over history. If the only reasonable action given the economy, is to move to higher ground. Humanity is not going to stop natural rhythms. Constructing dikes throughout the state is impractical. Regulations should prohibit development in at risk areas and all funding for stop gap measures, such as beach replenishment, should cease or be funded totally by the landowner.
- Not sure that there is a clear well articulated state policy or initiative.
- I am very concerned about (1) insuring the accuracy and integrity of the data upon which any SLR
  conclusions are based, and (2) the inevitable conflict between contemplated regulatory initiatives and
  existing property uses and private property rights.

- Please discuss in subsequent presentations the effects of the unexpected rapidly rising rate of the melting of surface ice in Greenland and Western Antarctica.
- You have a long awareness challenge! Look for ways to get more information to more people such as newspaper articles and community meetings.
- Recommendation for financial incentives to mitigate or abate impact of SLR from both the private property
  owner as well as municipalities. At the same time, do not mandate or intrude into personal property issues.
- Would like to see more of this information in the local newspapers
- Please consider the fact that your committee may be being used to promote an agenda not known to the
  members, as a means to insure local compliance to the U.N. Convention on Biological Diversity, wetlands
  project, as a vital step in attaining sustainable development. This is set forth in the U.N. "Agenda 21"
  program. If you are not familiar with it, look it up!
- No, except possibly how will we deal with the impacts to sequestered toxins at existing landfills and disposal
  areas that will be inundated.
- The presentation needed, I think, 3 areas of more in-depth analysis:
  - 1) The potential economic/financial impact
  - 2) A 25 -50 year scenario in the presentation. It is truly hard for the public to grasp 100 years
  - 3) Impact of climate change: increased storm activity, storm surge, etc.
- I think the best and cheapest way to fix Primehook's problem is to dredge the beach and bay. The sand
  and filler could be dumped on the beach benefitting the citizens and commerce. Actually, it would help all of
  Delaware's beach area.
- No, you have a very dynamic and diverse background to consider the problem

#### Did you find any inaccuracies or problems with the information displayed today? Please describe.

- What causes global temperatures to change?
- Poster: What causes Sea Levels to Change? The section dealing with global temperature change seems to
  indicate that most of climate change is resulting from natural forces and therefore there is little we can do to
  mitigate it.
- I struggled (as you did) with the maps. They do not readily convey the information. A possibility would be to start with what questions (5) the maps should answer and design the maps with that in mind.
- No -- very well presented
- No, I thought the computer models and available displays were accurate.
- We now know some information being presented is based on false science.
- I do not agree with your findings that the sea will rise and swallow us up!
- fire/Ems stations- seemed to be a lot of Ems stations. Need to distinguish between the two. Police station ids. Business impacts need to be more detailed.
- No, very informative.

- Did not review in enough detail, though the 2 computer stations were a great idea.
- No, but I have little or no ability to question the data or the conclusions drawn from the data. That is why I
  came, to learn more and educate myself.
- Display 4 contains the statement "approximately 3% of Delaware's 411,000 homes could be inundated by 3.3 feet (1 meter) of SLR". My comment is that SLR inundates land that is low, not homes. Codes exist along the coast which requires homes to be elevated more than 3.3 feet above sea level.
- I am not keen on the display that shows the reasons for SLR. The Milankovitch cycles and sunspot activity
  are relatively minor factors which take away from the main threat.
- Because the projections are on a gross scale, actual local elevations do not show.
- No, Committee seems to be using an even handed approach.
- No, but a cost study would have enhanced the presentation along with some short term analysis. You have bent over backwards to make a scientific presentation without using panic ideology.
- I found the presentation very professional. The DelDOT people were very friendly as were the volunteers, it
  was just a depressing subject.
- No, it was reflective of a balanced approached to addressing a complex problem.

## Please tell us what aspects of sea level rise might impact you, your home, or your community.

- I'll be gone by the time SLR gets really bad, but I worry about my grandchildren and their children.
- None to my home, at least for another 284 years according to my calculations however, it will have an impact on my community. Things will change the question is how well will we change with SLR?
- If Delaware makes taxpayers pay for risky investments, specifically homes that should not have been built so close to the water, I will have less money. Where is the County responsibility?
- Sea level rise will affect all of us living in areas adjacent to coastal Sussex County. It will affect tourism, agriculture, and real-estate.
- I live and work in a coastal town. SLR could affect my home, job, and recreational opportunities.
- flooding of our business community in Milton.
- 1.0 meter SLR, Delaware is sinking.
- Infrastructure availability.
- I live in Georgetown; your maps show that my house will stay high and dry no matter what.
- I live inland but my family has a beach house so I am concerned about storm surge. But I am also concerned about all regional impacts especially on natural resources and infrastructure.
- I am from Primehook, so the roadway for emergency need is impacted plus the loss of dunes and beach front.
- Habitat migration/ adaptation, impacts on drinking water, and impacts on wastewater treatment.
- Wells, septic, damage from storms pushing water further inland.
- No but the material presented is fairly dense.

- Loss of home very shortly.
- Not much, fortunately, as I live on relatively high ground.
- I till 3 farms in South Bowers. We used to see saltwater intrusion onto our land once every 5-6 years. Now it happens 3-5 times a year. Changes have been seen over the past 15 years. We have lost about 30 acres that are no longer tillable because the soil is too salty. flooding by saltwater is so frequent that salt never has a chance to be flushed out of the soil.
- I will probably have to pay taxes to make up for the stupid land use decisions county officials have made.
   They are so keen to get real-estate transfer taxes that they ignore SLR.
- I live in a relatively low lying area in Kent County. Concerned about community water and wastewater
- Loss of property, economic decline, loss of quality of life, environmental changes.
- A significant point of vulnerability in Lewes is the bridge over Canary Creek. It currently is too low! The bridge floods regularly and a strong northeast wind can keep water, from storms, in the creek for days. This bridge, when built, was not properly constructed and the approaches sink quickly after they are repaired by DELDOT. This bridge has served as a crabbing and fishing point for 75-100 years. Please do not eliminate this local feature of the bridge if you choose to rebuild a better bridge over the Canary Creek.
- I live in South Bethany on a canal!
- I live in South Bethany and my home is about 8 feet above sea level.
- I live in the back of Primehook Beach. That marsh and strip of land has been our barrier island but it is dissolving quickly. It is very frightening, as we have worked for 25 years for our home and property.
- Land value decrease as it will become less desirable to come to the beach areas.
- SLR will significantly reduce our opportunity for recreational benefits, damage the ecosystem, put our homes at risk for flooding, and cause economic hardship.
- My home may be completely destroyed. The value has declined drastically and it is scary. I see sale signs going up with asking prices cut to the bone. They are good people and deserve better. Our road to Primehook is really dangerous but we are thankful for it.
- Communities will need infrastructure for roads and schools. For me personally and for my family, we are outside of the impact zone.

#### Please tell us what aspects of sea level rise you are most concerned about.

- Port Mahon roadway is problem already; Bombay Hook NWR
- Dealing with SLR is going to cost a lot of money. The Committee needs to hold more discussions about the value of vulnerable assets.
- Being smart about our adaptation methods. Who is responsible? If I buy a home that in 100 years will be
  under water and I am ok with that because it is on the beach and I am only looking 10-15 years ahead, then
  So What! The problem is 40 years from now, the owner of that home is screaming for a buyout at top dollar.
  Personal responsibility has to play into the strategy.
- Loss of wetlands!
- Be able to adjust in the future as new info about SLR becomes available.

- According to the models the community where I work is in big trouble.
- What can we do as individuals beyond AWARENESS?
- Economic impacts
- Little
- I have no concerns about sea level rise.
- All of them!
- Road inundation and critical infrastructure inundation.
- Engulfing our cottage with no option of relocation. Loss of property will impact us financially and our family sentiment since we built the cottage ourselves.
- Habitat migration and affects on surface water and groundwater resources.
- I would like to thank you for the information. Everyone involved is doing a good job and the State of Delaware should be proud to have people who are industriously applying themselves to their jobs.
- How will adaptation be paid for? Will emerging solutions be considered.
- Revert back to a beach replenishment agreement in exchange for public assistance. Then go for long range solutions.
- Why are we spending millions of dollars on Indian River Inlet Bridge when the roads to and from it will be under water?
- Future regulatory initiatives.
- Spending taxpayer money to benefit a small portion of people who live along the coast.
- I am most concerned about economically disadvantaged people who are without choices in dealing with SLR.
- flooding/inundation and salt water intrusion.
- Loss of property and the ability to provide health and safety services for the community.
- The government, through regulation and restriction of personal property use and denying citizens their right to private property i.e. the 4th Amendment the U.S. Constitution.
- Inundation of wetlands and existing infrastructure. Will the taxpayers have to bail out flooded homeowners in the coastal zone? Example: Primehook Beach?
- Impact on beach communities. When preparing public information after the recommendation phase, be mindful of how such information may impact property value and tourism in Delaware which is a substantial revenue source for the State.
- Should I move? Should we build dikes? Should we bring in a lot of sand? I could still get around in my boat.
- It is clear that our town will be inundated due to sea level rise. Our issue will be how do we plan for SLR now and not later. (Mayor of South Bethany)
- flooding. May allow for the distribution and spreading of toxic and carcinogenic chemicals.
- The increasing impact on groundwater and the drinking water around my house and the flooding potential,
- That people can ignore this issue. SLR is happening whether you believe it or ignore it!
- Risk of damage and flooding to property, degradation of the community from economic hardship,

infrastructure damage, and potential danger to evacuation routes and possibly even to overall evacuation.

- Complete flooding in the area which will happen and to a degree has happened several times recently.
- Cost to me and the community.

Please tell us if you feel that the Delaware Sea Level Rise Advisory Committee is on the right track or on the wrong track with its approach to planning for sea level rise.

- Right track x 12
- Right track. I will be interested to hear the solutions now that I know the issues.
- Right track with proper government representation.
- Wrong track. Reduce DNREC budget or eliminate department, it is getting too political.
- Wrong track. I think we are wasting a lot of money on studying sea level rise.
- Right track. Hope for rapid answers but know that research must be done.
- Right track, Brave for taking this issue on and focusing the public's attention.
- Right track for the long range. Wrong direction for the short range.
- Do not know enough yet to say for sure. It appears that the Committee is doing a good job of studying the issue
- Right track. There is a need to reassess what is going on along the coast and change what we are doing.
- Right track. Could be less conservative
- You did not make any suggestions for solutions. Should we move or spend a lot of money?
- Right track. Thank you for the great presentation and displays.
- This is a great track. You are carefully building the case for adaptation.
- Right track. This is going to be of upmost importance to all of Delaware in time, not just the coastal areas. All
  options should be investigated and evaluated.
- You are on a good track. I encourage you to continue to maintain your diverse group.

#### What information presented today was most useful to you?

- TV info and the SLR map viewer
- The ability to see the areas that will be potentially affected.
- Rate and extent of change.
- Computer availability
- Knowing your direction so citizens can resist.
- I enjoy looking at maps.
- It's very useful to listen to simple explanations of sea level rise. It's helpful for explaining to friends and family without putting them to sleep.

- All. Nice job by the presenter and facilitators.
- Scenarios/mapping
- All of it.
- The GIS maps and infrastructure display
- Ma
- Very good. The information was well presented.
- Include below-water-level sewer outlets for the Wilmington sewer system.
- Information on mapping
- Computer map overlay showing flooding at various elevations of SLR.
- Local information about my community provided by the computer maps.
- The website that allows us to look at the SLR maps on our home computer.
- Visuals showing potential inundation.
- Both the presentation and the displays.
- The data presented has been around for some time, I am waiting for the strategies and recommendations.
- Seeing what the Committee is doing.
- Computer maps that show the potential effects on our property.
- Everything. It was great to see that people are actually trying to address this issue.
- Computer maps and scenarios, well done.
- The information simply confirmed my thoughts.
- Social and economic impacts.

#### Do you have additional information or concerns you would like to share?

- The general public needs to understand SLR and be challenged to live more efficiently and use less energy.
   Please offer a plan to educate the public on what they can do and what we all must do to lower the impacts over time. We need our government to be proactive on this as well. Thanks for your efforts.
- Need to add wastewater plant in Milton.
- I am wondering why you are scaring people with this stuff when the sea is barely rising at all if at all. I do not believe in global warming which has now been renamed climate change. It is a hoax. I am sorry we are wasting so much time and money on this.
- Keep up the good work.
- Integration between the State and County governments regarding hazard mitigation plans.
- Perhaps your group could come to our Primehook Beach organization meetings with your exhibits on SLR or contact the Board chair, she is great at dispensing information to us non-residents by email.
- Many questions about how this research/data will be used. Could have been addressed during the
- You should have been more forceful with this information years ago to advise other agencies to pass zoning

and building codes to stop people from building in areas that will be under water. Laws could have been made to say if you build you cannot be bailed out by taxpayers.

- Support not allowing people to build in certain areas. Want the amount of sand on the beach to be reduced so that the shoreline can change naturally.
- Availability of GIS layers for 3rd party users to evaluate.
- Sussex County Government should participate.
- Why is Sussex County not listed as a member of the Advisory Committee?
- If the plan is that I should move then I should do it soon so that I can sell my property. I am 68 so I probably
  do not need to do anything but my children will have to worry about it.
- What should towns in the impact zone do? As more and more information about SLR "gets out", town officials will be asked to provide what we have in place to combat SLR. So the sooner the better in getting out the recommended solutions. Thank you for holding these public engagement sessions. I believe SLR is happening and I came tonight with the hope that the Committee would provide solutions with how to handle the impacts of SLR. (Mayor of South Bethany)
- The town offewes would like the SLR maps to download.
- Your maps should show:
  - A) the range of static sea level rise
  - B) the range of storm surge
  - C) the combination of A + B, which would be the real world worst case scenario
- Why are the Sussex County municipalities and Sussex County not represented on the Advisory Committee?
   Most of the ocean shoreline is in Sussex County! It is very disconcerting that many DNREC employees do not know the municipalities in Delaware, such as Henlopen Acres. What procedures are being developed to keep all municipalities involved and informed?
- Why is Sussex County not directly represented on the Advisory Committee? We should stop wasting time with determining why SLR is happening. It is happening and we need to keep moving forward.
- The public will have difficulty attempting to mitigate risk, increasing protection, or taking on other costly measures without a cost/benefit analysis. The Committee must continue to build the scientific argument that SLR is real and then add in the cost of adaptation options. Also we probably need to emphasize the rapidly changing trends this is so important- since the situation is accelerating and we do not want the maps to lead to panic. We need to build this into our UD campus tours. Can we build in the ecosystem changes that are likely to occur?

#### Comment Letter from Steve Callanen Chair, Southern Delaware Group, Sierra Club

38986 Bayfront Drive Ocean View, DE 19970 December 2, 2011

Susan E. Love, Resource Planner, Delaware Coastal Programs DNREC, Division of Soil & Water Conservation 5 E. Reed Street, Suite 201 Dover, Delaware 19901

Subj: Reduction of Indian River Inlet Depth Needed to Curtail Bay flooding

#### Attachments:

a) Tidal Prism Graph, CCMP, Appendix F, p. 2-1, June 1995.
b) Tidal Prism Graph, 2011 State of the Delaware Inland Bays, 23 Sep. 2011.
c) Indian River Bay Shoreline flooding, Callanen Photo 5109, 5-12-08.
d) Indian River Bay Shoreline flooding, Callanen Photo 5115, 5-12-08.
e) Indian River Bay Shoreline flooding, Callanen Photo 5120, 5-12-09.
f) Indian River Bay Shoreline flooding, Callanen Photo 5130, 5-12-09.
g) Indian River Indiet - ACOE Multi-beam survey data - Mar 1999 Silde42
h) IR Indet Cross Section, figure 3.14
l) IR Indet Cross Section, figure 3.15
l) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Cot. 2008.
k) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, May -Aug. 2011.
n) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Aug. -Nov. 2011.
n) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Aug. -Nov. 2011.
n) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Aug. -Nov. 2011.
n) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Aug. -Nov. 2011.

Dear Ms. Love,
I enjoyed talking with you after your Sea Level Rise Engagement Session presentation on November 29th in Lewes.
Please consider the comments in this letter as my "Comment Form" reply.

My primary concern, which has not been addressed by the Sea Level Rise Advisory Committee, which astonishingly has no representative from Sussex County, is the rise in water levels around the shores of Delaware's Inland Bays due to self-scouring of Indian River Inlet. According to Robert Scarborough, DNREC Research Coordinator & Environmental Scientist, whom I also spoke to on Tuesday evening, it is unlikely that this problem will be addressed for at least two years. This delay in taking action on this serious problem is inappropriate and downright foolish.

It is submitted that tidal-prism data (Attachments (a) & (b)) indicates that the rate of water level rise on the shorelines of the Inland Bays exceeds future flooding rate increase estimates attributed strictly to global warming.

The 320-square-mile Inland Bays watershed has experienced well documented severe flooding on numerous occasions, including in November 2009 during tropical storm Ida and in May 2008 (Attachments (c), (d), (e) & (f)). Bay flooding is adversely impacted not only by major storms and sea-level rise, but also by the extreme self-scouring of Indian River Inlet, which provides the primary connection between Delaware's Inland Bays and the Atlantic Ocean.

A greater volume of water exchange between the ocean and the Bays now occurs on each tide cycle, due to extreme self-scouring of the Inlet (Attachments (g), (h) & (i). The cross-sectional area of Indian River Inlet, 500-feet east of the bridge, increased from approximately 800 square feet in 1936 to nearly 22,000 square feet in 1991. The cross-

sectional area of the channel, 600-feet west of the bridge, increased from approximately 900 square feet to over 31,000 square feet during this same time period. The volume of water flowing through the Inlet on each tide cycle roughly tripled from 1939 to 1969, then almost doubled from 1969 to 1988. The depth of the Inlet has dramatically increased from 15-feet to over 100-feet in some places; and as a result, high tides in the bays are higher and low tides are lower. Low tide water levels in Indian River Bay are 12-inches lower than they were 50 years ago. (Delaware Inland Bays Comprehensive Conservation and Management Plan (CCMP), Appendix F, D. 7. June 1995.) As the Inlet's cross-sectional area has increased, it has become less effective as a deterrent of excessively high water levels in the Bays.

The attached Indian River Bay and Rehoboth Bay "tidal prism" graphs illustrate the increasing tidal action, and hence the corresponding higher high tide and lower low tide water levels. (Delaware Inland Bays Comprehensive Conservation and Management Plan (CCMP), Appendix F, p. 2-1, June 1995.) This same "tidal prism" data was recently published in the 2011 State of the Delaware Inland Bays.

Because of the significant progress made over the past decade in eliminating large point sources of pollution around the Bays, it seems highly doubtful that significantly reducing, or halfing, further scouring of the Inlet will detrimentally impact adequate flushing action, which transports excess harmful nitrogen and phosphorus nutrients from the Bays to the ocean.

Sea-level rise and typical nor easter storms increase flooding impacts, not only on private property and public roads surrounding the Bays, but also on the leaching of toxic heavy metals into Bay waters from the unlined 144-acre Burton Island coal ash landfill adjacent to the Indian River Power Plant.

The Burton Island site is now mostly surrounded by riprap; however, U. S. Geological Survey tide height measurements taken at Rosedale Beach, almost directly across Indian River from the power plant, show that on numerous occasions in 2008, 2009 and 2011, for which data is available (Attachments (j), (k), (l) & (m)), water levels have exceeded the top of the pier on which the USGS water height gage is located. In October 2009 and August 2011 the excessively high water levels caused the water height gage to malfunction, thereby preventing accurate recording of these events. The USGS indicates that a maximum water elevation of 6.99 feet occurred at this site on Feb. 5. 1998. (Attachment (m)).

It was shocking and disturbing to learn at a 2008 DNREC public hearing that 26 years after Delmarva Power and Light ceased dumping coal ash from the Indian River Power Plant onto Burton Island, 26 of 26 offshore sediment samples were discovered to contain seven heavy metal pollutants identified as "Constituents of Potential Concern for either human or ecological receptors."

These metals include aluminum, arsenic, barium, cobalt, copper, mercury and nickel. Delaware Toxic Release Inventory Reports identify compounds of arsenic, cobalt and nickel as carcinogens.

An ecological risk assessment published by Shaw Environmental Inc. in March 2008 states, "There is a potential for adverse affects to benthic invertebrates in the sediment along the shoreline of Burton Island due to ar

NRG's remediation plan for Burton Island has thus far consisted of leaving contaminated offshore sediment in place and adding riprap along the shoreline. Although this riprap helps inhibit erosion of shoreline embankments, the synthetic fabric underlay is permeable, and therefore does not prevent leaching of the landfill pollutants into bay waters. The riprap fails to eliminate the long-term pollution problem, which is exacerbated by high water levels and wave action, especially during typical Nor'easter storms.

To the best of my knowledge, the impact of sea level rise has not even been considered in the ongoing Burton Island remediation analysis or discussed in the reports developed to date. The Sea Level Rise Advisory

Committee should focus attention on this omission.

To prevent long-term worsening of Inland Bay flooding impacts, it is necessary for DNREC and/or the Army Corps of Engineers to reduce the volume of water entering the Bays on each tide cycle by reducing the Inlet's depth and hence its cross-sectional area.

According to an ACOE report, "inlet scour continues and presently poses what may prove to be the most difficult and costly of the coastal engineering challenges presented in the 100 plus years since locals first petitioned the Government for a jettied inlet." Assuming this statement to be correct, it is respectively submitted that the time to start working on remediation of this worsening problem is NOW. Sincerely.

Steve Callanen, Chair, Southern Delaware Group, Sierra Club

302-539-0635 (h)

Copy to: Senator George H. Bunting, Jr., 20th Senatorial District, Senator F. Gary Simpson, 18th Senatorial District, Joan R. Deaver, Sussex County Council, District 3, Collin O'Mara, DNREC Secretary, Sarah W. Cooksey, DNREC Administrator, Delaware Coastal Programs, Robert W. Scarborough, Ph.D., DNREC, Research Coordinator & Environmental Scientist, Kelly Valencik, DNREC, Coastal Programs, Chris Bason, Acting Director, the Delaware Center for the Inland Bays, Doug Parham, Chair, CIB, Citizens Advisory Committee

<sup>&</sup>quot;"Delaware Inland Bays Comprehansive Conservation and Management Plan," Appendix F, figure 3.16, p. 3-130, Jun 1995.

<sup>12</sup>The DE Center for the Inland Bays, '2011 State of the DE Inland Bays,' p. 15, September 23, 2011.

<sup>&</sup>lt;sup>13</sup>http://waterdafa.usgs.gov/de/nwis/uy?ob\_00065=on8format=gif\_default8.period=21&site\_no=01484540 <sup>14</sup>The USGS tide gage was not installed until April 1991.

<sup>1957</sup> YEARS OF COASTAL ENGINEERING PRACTICE AT A PROBLEM INLET: INDIAN RIVER INLET, DELAWARE," by Jeffrey A. Gebert, Keith D. Watson, A. M., ASCE and Augustus T. Rambo.

Responses to Steve Callanen Letter

Point of Clarification.

The item that I referred to that would not happen for probably two years is the expansion of the DEOS (Delaware Environmental Observing System) Coastal Storm Early Warning System. The system is now in place for Kent County (http://www.deos.udel.edu/coastal\_flood) and researchers from the University of Delaware are currently expanding the coverage to go from Lewes to the City of New Castle. The next phase if funded will include the piedmont area of northern New Castle County and the Inland Bays. These two areas are last because of the complications and extra research required due to increased surface runoff in the piedmont region and difficulty in predicting flooding in the Inland Bays due to restricted tidal flows through the Inlat combined with runoff

Thank you

Robert W. Scarborough, Ph.D.DNREC//Delaware Coastal Programs/DNERR

Steve

Thank you for your comments – we will include them for consideration by the sea level rise advisory committee.

You already received and email from Dr. Scarborough regarding the expansion of the Delaware Environmental Observing System Coastal Storm Early Warning System into the Inland Bays area, if funded.

I also wanted to let you know that modeling of the impact of sea level rise on the NRG ash disposal area was conducted as part of the recent remedial investigation by DNREC Site Investigation and Restoration Section. The reports are available here:

http://www.dnrec.delaware.gov/whs/awm/Info/Pages/NRGIndianRiver.aspx

The impacts of sea level rise are specifically addressed in the third document listed – NRG's Response to DNREC's comments. If you have questions about the results, please call Greg DeCowsky at SIRS who will be able to explain the technical details much better than I can.

Again, thanks for your comments.

Regards,

Susan E. Love

Delaware Coastal Programs

#### Comment Letter from Claudine Bodin

Wednesday, November 16, 2011 - 12:20 PM

Subject: Government Inaction or Sea Level Rise?

From: Claudine Bodin

Valencik Kelly J. (DNREC): Senator Simpson: Kenton Harvey (LegHall): Hill Jennifer A. (Governor): Dan ASHE: Glen Robert A (DOS) brenda I. schillaci@mssb.com. Ron; Tena Alexander; Devores; trainster@aol.com: Diane McConnell To:

Monday, November 14, 2011 8:18 PM

Government Inaction or Sea Level Rise?

Because of an injunction brought forth by PEER, there has been massive, destructive flooding at Primehook Beach. Is this a case of "sea level rise" or "deferred maintenance"? The only reason this sort of flooding is not a current crisis at Rehoboth or Dewey Beach is because those communities can count on dune and beach replenishment done paid for by the state of Delaware, whenever needed. I clearly remember the Rehoboth boardwalk being destroyed by a storm . . . and then fixed. If those repairs had been neglected where would

What we are witnessing and experiencing at Primehook is a breach of duty by the state and federal governments -a matter of neglect and deferred maintenance in a National Wildlife Refuge abutting a great community. Primehook tax payers are in a constant crisis of being flooded, stranded, and their very lives left in peril. They must deal with this crisis mostly on their own. Some government agencies and representatives have helped and are currently seeking justice for the community. But the crux of the problem, the breached dunes, is not being addressed. I believe this has more to do with breach of duty, exacerbated by the PEER lawsuit (that was finally defeated late this summer) than a matter of sea level rise.

Primehook property owners have been left with properties that cannot be sold. Even if someone wanted to buy one of the houses currently for sale, mortgage lenders would require flood insurance; but that is no longer available at Primehook because of the neglect -not neglect by the Primehook property owners --they have been fighting to fix this problem for years!

At this point one of two things should happen:

- 1) The breached dunes should be fixed and consistently maintained, or;
- 2) The government must accept their breach of duty and buy the land from the owners who have been left to confront flooding as no other property owners in Delaware have had to.

What is Happening at Primehook is an Out-of-Control Short-Term Problem that has Left Residents in a Horrible Quandary

I have faith that what is happening at Primehook can be resolved. The former fresh water refuge is at a fragile, irreparable tipping point. I hope that the state of Delaware and the National Wildlife Refuge system (Department of the Interior) can appreciate that and take swift action for both the migratory birds and other wildlife dependent on that habitat as well as the property owners on beautiful Primehook Beach.

Claudine Bodin

## F - Dissenting Opinion Statements

Expertise, opinions and advice from members of the Sea Level Rise Advisory Committee was essential to the development of this sea level rise vulnerability assessment. Advisory Committee members outlined desired information, helped obtain datasets, drafted individual sections of the document, and reviewed draft and final products. Committee members also voted to finalize and publish the document.

Voting procedures approved by the Sea Level Rise Advisory Committee require the affirmative vote of 2/3 of the total committee membership to pass any motion. Committee members also recognize that dissenting opinions add context to a discussion and should be documented for consideration in future work. As a result, the voting procedures also outlined a process to allow Advisory Committee members who do not agree with a recommendation to have their opinions included in committee products as a dissenting opinion.

Two Advisory Committee member organizations have submitted dissenting opinion statements for inclusion in this vulnerability assessment, the Home Builders Association of Delaware and the League of Women Voters of Delaware. The Home Builders Association of Delaware registered the sole "no" vote for the finalization and publication of the Vulnerability Assessment. The League of Women Voters of Delaware voted to approve this document with the inclusion of the additional information contained within their dissenting opinion.

The two dissenting opinions are presented on the following pages.

#### MINORITY STATEMENT BY THE HOME BUILDERS ASSOCIATION OF DELAWARE

The Home Builders Association of Delaware (HBADE) appreciates the work effort of the Sea Level Rise Advisory Committee toward addressing the potentials of sea level rise. Our Board of Directors has approved the following position statement, and have asked our representative Keith Rudy to submit this on the behalf of HBADE.

Over the last 110, the rate of Sea Level Rise and Subsidence in Delaware has averaged about 3.35 mm per year. Over the next 100 years, at this rate, we expect that an addition 0.34 meters of rise. Accounting for an increased rate of sea level rise that some feel may occur over the next 100 years and in order to plan conservatively, the Home Builders Association of Delaware supports the planning for 0.5 meters of sea level rise over the next 88 years at the current time.

One half meter is consistent with the conservative estimates by the International Panel on Climate Change (IPCC) and NOAA for global sea level rise over the next 100 years. Additionally, the HBADE supports a close monitoring of the actual sea level rise over the next twenty years in order to determine if the 100 years trend will exceed 0.5 meters of rise. Even at the most catastrophic estimates of sea level rise being considered by DNREC, we would not exceed 0.5 meters in 30 years and we would still have adequate time to plan for this level if it appears that the trend is towards more than 0.5 meters of rise in the next 100 years.

We appreciate the opportunity to submit our position and hope that it is helpful to the Advisory Committee.

Submitted by Howard Fortunato, Executive Vice President, HBADE on April 26, 2012

MINORITY STATEMENT BY THE LEAGUE OF WOMEN VOTERS OF DELAWARE ON THE SEA LEVEL ADVISORY COMMITTEE VULNERABILITY ASSESSMENT REPORT

- 1 The DNREC Coastal Programs Staff did a good job of writing the first draft of the 244-page Vulnerability Assessment Report and of including most of the suggestions made by yAdvisory Committee members, including a number made by the League, in the second draft. There are however three important issues that should be addressed on which we were unable to reach a consensus with the staff and Advisory Committee to include. We describe them, with references to our information sources, in this Minority Statement. The first set of three summarizes the issues; the second set gives more detail with references. The page numbers in parentheses refer to the Coastal Programs' second pdf draft of the report.
- 1. Delaware has the lowest average elevation of any state in the U.S., so that it is especially vulnerable to sea level rise.
- 2. The evidence that the rate of sea level rise is increasing and is very likely to keep increasing for many decades to come was downplayed in the report as adopted by the Committee, in spite of evidence that the rate of ice loss from both Greenland and Antarctica is increasing and that the loss of ice from these two huge ice sheets will dominate the future rate and extent of sea level rise.
- The report fails to mention that Delaware's vulnerability to climate change is caused not only by sea level rise using the "bathtub model" adopted by the Committee, but by storm surges and wave heights that are likely to increase in a warming world.
- Delaware is particularly vulnerable to the effects of SLR not only because of its location and dependence on the coast, but also because it has the lowest average elevation of any state in the U.S., only about 60 ft or 18 m.¹ (Pages xi and 3)

We suggested inserting on Page 3 right after the sentence starting with "Delaware is particularly vulnerable ..."Delaware has the lowest average elevation of any state in the U.S., only about 60 ft or 18 m."

2. We strongly dislike the sentence on Page 7, "While it cannot be proven with certainty, climatologists have predicted that the rate of sea level rise occurring today will likely become greater in the decades to come." (emphasis added) We can't understand the reasons for not simply replacing it with, "Climatologists have predicted that the rate of sea level rise will likely become greater in the decades to come." The new wording provides the reader with the idea of uncertainty with the words, "predict" and "likely." We object to the phrase, "While it cannot be proven with certainty. ..." because it may give the lay reader the mistaken impression that the expectation of increasing rates of future sea level rise is quite uncertain, and that therefore adaptive action can be put off.

The U.S. Army Corps of Engineers (USACE) issued a circular in October 2011 providing guidance for incorporating the direct and indirect physical effects of projected future sea-level rise across the life cycle of USACE projects and systems.<sup>2</sup> The USACE guidance predicts an accelerating rise at least until 2100. The form of an equation describing the acceleration was taken from a 1987 NRC report.<sup>3</sup> At that time (25 years ago) it was not known whether the mass of ice on Antarctica was increasing or decreasing; it was thought that the snow and ice added by more annual snowfall in a warming world might exceed ice loss due to melting and rativing

A recent paper published in 2011 by research scientists E. Rignot et al.<sup>4</sup> - including two from the Cal Tech Jet Propulsion Laboratory and one from the National Center for Atmospheric Research - who have studied the ice sheet mass balance for Greenland and Antarctica over the last two decades, reports that both Greenland Antarctic ice sheets are losing mass at accelerating rates,<sup>3</sup> and that the combined acceleration is 3 times larger than that of other glaciers. They write: "If this trend continues, ice sheets will be the dominant contributor to

## F - Dissenting Opinion Statements

sea level rise in the 21st century." The acceleration of ice loss from Greenland, which is caused in part by the increased rates of sliding and calving of glaciers, is supported by earlier papers from NASA.6

3. The report focuses too narrowly on its "bathtub" model of sea level rise and fails to point out that the vulnerability of some resources - like people's homes - depends not only on the gradual increase in the mean higher high water (MHHW) of high tides, but also on episodic storm surges and waves that are likely to increase in height with global warming and that need to be added to relative sea level rise to assess vulnerability along the coast. The U.S. Global Change Research Program states: "There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures."7 We would like to have seen a figure in the report, similar to the one defining MHHW (Page 10), showing tide gauge measurements on the Delaware coast covering a number of days that include a period of storm activity. One example would be the passage of Hurricane Irene up the Delaware coast last year. In that case the damage was much less than feared because the highest storm surge was short-lived and came at an especially low tide (new moon).\* Another possibility would be the nor"easter of 1962, which lasted through five high tides, produced waves 20-40 feet high, and devastated the Delaware coast.9

A study of the intensity of wave action in the northeast Atlantic, using microseismometers to measure the shaking of the coast, indicates that wave action has been increasing as the water temperature has been increasing.10 The same may be true of our Mid-Atlantic coast. More energetic wave action is expected to increase the rate of coastal erosion and make it harder to protect coastal resources like marshes.

Submitted by Chad Tolman on June 4, 2012 for the LWV of Delaware

<sup>&</sup>lt;sup>5</sup>U.S. Census Bureau, Statistical Abstract of the United States, Chapter 6, Geography and Environment, p. 215, 2004-2005. At: http://www.census.gov/prod/2004-pubs/04-statab/nen-ord

<sup>&</sup>lt;sup>2</sup>SEA-LEVEL CHANGE CONSIDERATIONS FOR CIVIL WORKS PROGRAMS, U.S Army Corps of Engineers, Circular No. 1165-2-212, Oct. 1, 2011. At: http://planning.usace.army.mil/toolbox/library/ECs/EC1165221/2Nov2011.ddf

<sup>&</sup>lt;sup>3</sup>Responding to Changes in Sea Levet: Engineering Implications, NRC, 1987. At: http://www.nap.edu/openbook.php?record\_id=1008&page=30

<sup>\*</sup>E. Rignat, I. Velicogns, M. R. van den Broeke, A. Monaghan and J. Lenaerts, Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophysical Research Letters, Vol. 308, 2011. At: http://www.agu.org/pubs/crossref/2011/2011GL046583.shtml

The measured combined acceleration from Greenland and Antarctica corresponds to an annual increase in the rate of global seal level rise of 0.10 mm/yr, so that in 2 (00.1 file the rand continues, these ice sheets by themselves will contribute 10.7 mm to the seal level rise that year. This can be compared with the average annual global rate of 1.7 mm dumple heats certainly from both water warming and ice on land melting.

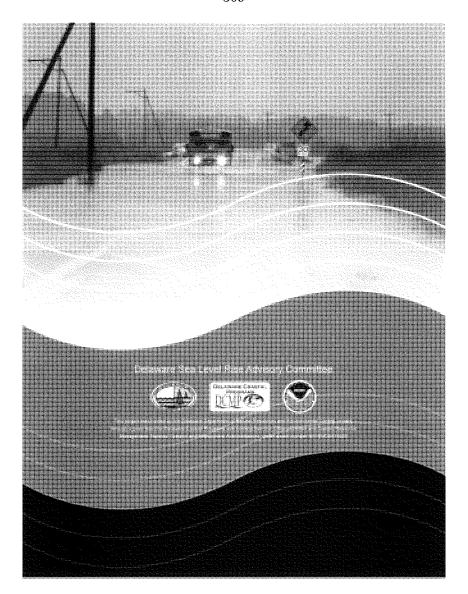
Triendind for the Jose Oxcible in Past Decade, Raising Sea Level Faster, NASA Per Proulison Laboratory, Feb. 16, 2008. At http://www.jcl.nasa.gov/news.news.cfm?rdesas=2006-423
Jacobshaw Glance Retreat, NASA Earth Observatory, July 15, 2010. At http://wenthosservatory.nasa.gov/OTD/view.php?rd=44625

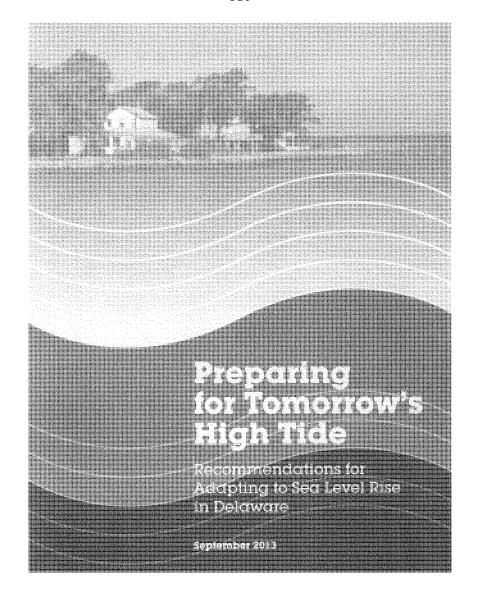
<sup>\*</sup>Hurricanes and Climate Change, in Hurricanes - a Compendium of Hurricane Information, USGCRP, updated Sept. 15, 2008. At: http://www.usgorp.gov/ usgorp/links/hurricanes.htm For a good book on hurricane history and science by an MIT professor see Kerry Immanuel, Divine Wind – The History and Science of Hurricanes, Oxford University Press, New York, 2005.

<sup>&</sup>lt;sup>a</sup> Hurricane Irene "Looking Bod" for U.S.—Moon May Make It Worse, National Geographic Daily News, Aug. 25, 2011.
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<sup>&</sup>lt;sup>9</sup>The Great Nor easter of 1962 - Delaware's Storm of the Century, published by the UD Sea Grant College Program in cooperation with DNREC. At: http://www.deseagrant.org/sites/deseagrant.org/files/product-docs/1962\_storm\_of\_the\_century.pdf

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#### **About this Document**

This document was developed by Delaware's Sea Level Rise Advisory Committee and by staff of the Delaware Coastal Programs section of the Delaware Department of Natural Resources and Environmental Control (DNREC). It is intended to assist government agencies, businesses and individuals make well-informed choices about preparing for and responding to sea level rise. Its central component is a set of recommendations for building the state's ability to adapt to sea level rise. The document also contains background information about adaptation measures that can be taken to decrease Delaware's vulnerability to sea level rise and provides a set of guiding principles for consideration by those choosing adaptation measures.

The recommendations contained in this document were approved by the Sea Level Rise Advisory Committee and have been submitted to DNREC Secretary Collin O'Mara for consideration and for further collaboration with other state cabinet agencies. It is envisioned that a collaborative team composed of government agencies, businesses and individuals will be brought together to seek support and resources to implement the recommendations.

Other Documents in the Preparing for Tomorrow's High Tide Series

Progress Report of the Delaware Sea Level Rise Advisory Committee (November, 2011)

Sea Level Rise Vulnerability Assessment for the State of Delaware (July, 2012)

Mapping Appendix to the Sea Level Rise Vulnerability Assessment for the State of Delaware (July, 2012)

#### For More Information

For more information about the Sea Level Rise Advisory Committee or this document, please contact:

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## Preparing for Tomorrow's High Tide:

## Recommendations for Adapting to Sea Level Rise in Delaware

Final Report of the Delaware Sea Level Rise Advisory Committee

#### Lead Authors:

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Delaware Department of Natural Resources and Environmental Control

Delaware Coastal Programs

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Copies of this publication are available at the Delaware National Estuarine Research Reserve, 818 Kitts Hummock Road, Dover, Delaware and online at http://de.gov/slradaptplan.



## STATE OF DELAWARE DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENTAL CONTROL OFFICE OF THE SECRETARY

DELAWARE COASTAL MANAGEMENT PROGRAM 5 E. REED STREET, SUITE 201 DOVER, DELAWARE 19901 Phone: (302) 739-9283 Fax: (302) 739-2048

August 15, 2013

The Honorable Collin P. O'Mara Secretary Department of Natural Resources and Environmental Control 89 Kings Highway Dover, DE 19901

Dear Secretary O'Mara:

In September 2010, the Delaware Sea Level Rise Advisory Committee was convened under your directive to assess Delaware's vulnerability to the effects of rising sea levels and to provide recommendations for long-term policy decisions, management actions and resource investments. On behalf of the Committee, I am pleased to provide you with this document, *Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware.* The completion of this document fulfills your directive and represents the culmination of nearly three years of work by our committee and Department of Natural Resources and Environmental Control (DNREC) staff.

This document contains 55 recommendations that, if implemented, will improve Delaware's ability to adapt to sea level rise. Recommendations described in this document were vetted by the public at a series of engagement sessions and have the support of at least two-thirds of committee membership. Committee members have confidence that you will implement those recommendations that are under the purview of DNREC and ask that you strive to seek cooperation from other state agencies, local governments, businesses and citizens for implementation of recommendations that may be outside of DNREC's sole authority.

With the completion of the recommendations, this document and the significant public outreach that accompanied them, the state is poised to become resilient to the effects of sea level rise. Thank you for your leadership on this issue; your support and vision have been integral to completing this plan. We look forward to working with you to see its components become reality.

Sincerely,

Sarah W. Cooksey, Chair
Delaware Sea Level Rise Advisory Committee

Delaware's good nature depends on you!

The organizations listed below, through the signature of their duly appointed representative, herby  $acknowledge\ their\ participation\ in\ the\ development\ of\ the\ Recommendations\ for\ Adapting\ to\ Sea\ Level$ Rise in Delaware:

John Taylor Delaware Chamber of Commerce

Mark Davis

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Son Knop Kurt Reuther/Don Knox

Delaware Department of Safety and Homeland Security

Richard Perkins

Delaware Division of Public Health

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Delaware Farm Bureau

The Honorable Quinton Johnson Delaware House of Representatives

Delaware Insurance Commissioner's Office

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Brenna Goggin

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Ruth Ann Jones/Andrea Godfrey

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Keith Rudy/Kevin Whittaker Homebuilders Association of Delaware

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Delaware League of Local Governments

Marcus Henry/Karl Kalbacher New Castle County

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Positive Growth Alliance

Jeff Shockley Sussex County

Richard Jones
The Nature Conservancy

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### **Executive Summary**

Delaware's economy and quality of life are linked to its shores, its vast expanses of tidal wetlands and its fertile farm fields. Because of its location, low average elevation and dependence upon coastal resources for jobs and recreation, Delaware is particularly vulnerable to the effects sea level rise, including loss of low-lying land and structures, saltwater intrusion into groundwater and surface water and increased coastal flooding during storm events.

Delaware's Sea Level Rise Advisory Committee was established to investigate the state's vulnerability to sea level rise and to provide recommendations about how to best prepare for higher sea levels. The advisory committee was convened in November 2010 by invitation of Collin O'Mara, Secretary of the Delaware Department of Natural Resources and Environmental Control (DNREC). The advisory committee is composed of members from a wide variety of stakeholder groups including state agencies, local governments, citizen organizations, business organizations and environmental organizations.

The publication of "Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware" marks the completion of the advisory committee's work. The central component of this document is a list and description of 55 recommendations for adapting to sea level rise in Delaware. These recommendations focus on building the necessary capacity for Delaware agencies, local governments, businesses and

individuals to plan for and put into place strategies for responding to sea level rise.

#### Sea Levels are Rising

Globally, sea levels rise as the earth gets warmer. This occurs for two primary reasons: (1) as ocean water warms, it expands and causes the average level of the ocean to increase, and (2) as land-based glaciers and ice-caps melt, the melt-water empties into the oceans and causes the average level of the ocean to increase. In addition, locally, sea levels can rise as a result of downward vertical movements of the earth's crust'.

A combination of these factors is occurring in Delaware today, resulting in a local rate of sea level rise that has been about twice the global average. At the long-term tide gauge in Lewes, the observed sea level trend is 0.13 inches per year (or 13 inches over a 100-year period)<sup>2</sup>. The global average trend for the twentieth century was 0.07 inches per year. It is anticipated that both the local and global rate of sea level rise will accelerate in the coming decades due to climate change which is expected to increase the rates of glacier and ice sheet melt as well as rates of ocean water expansion<sup>3</sup>. A technical workgroup established by DNREC in 2009 reported that by 2100, this acceleration of sea level rise rates could cause the level of Delaware's oceans, bays and tidal rivers to rise between 1.6 feet (0.5 meters) and 4.9 feet (1.5 meters) above their present levels 4.

From Williams, et al., 2009. Available online: http://library.globalchange.gov/groducts/assessments/2004-2009-syrithesis-and-assessment-products/sap-4-1-coastal-sensitivity-to-sea-level-rise-a-focus-on-the-mid-atlantic-region

<sup>\*</sup>Long term tide gauge data is maintained by the National Oceanic and Atmospheric Administration and is available online: http://www.tidesandcurrents.noaa.gov/sltrends/sltrends\_states.shtml?region=de

From Williams et al., Available online: http://library.globalchange.gov/products/assessments/2004-2009-synthesis-and-assessment-products/sap-4-1-coastal-asseslivity-to-sea-level-rise-a-focus-on-the-mid-atlantic-region

<sup>&</sup>lt;sup>4</sup>From Sea Level Rise Technical Workgroup, 2009. Available online: http://www.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Final%20 and%20Signed%20DNREC%20SLR%20scenarios.pdf

#### Delaware is Vulnerable to Sea Level Rise

Using these future scenarios as a guide, Delaware's Sea Level Rise Advisory Committee comprehensively assessed the impact of sea level rise on Delaware's communities, public safety, economy, infrastructure and natural resources. They found that, between 8% and 11% of land statewide is within an area that could be inundated with water at high tide<sup>5</sup> by 2100. Within those potentially inundated areas lie homes, industrial areas, roadways, protected land, wetlands, and wastewater facilities. In addition to inundation, saltwater intrusion into groundwater and surface water was identified as a significant issue, as was rising water tables and increased risk of damage from coastal storms. With each of these potential impacts come a number of secondary effects including loss of homes, reduction in employment opportunities, releases of contaminated material from industrial sites, increased drainage problems, and corrosion of pipelines among others6

The results of this comprehensive assessment of the state's vulnerability to sea level rise underscore the importance of adapting to sea level rise.

#### Adapting to Sea Level Rise

In a broad sense, adaptation means "adjusting" to new conditions and taking steps to moderate and cope with the effects of sea level rise. These steps can be planned and implemented at a variety of geographic levels, and by a variety of stakeholders. In Delaware and in many other locations, the process of adaptation involves two distinct efforts: (1) planning and implementing adaptation measures, and (2) building adaptive capacity.

Adaptation measures are on-the-ground actions that can be taken to prepare for sea level fise in a particular location. These measures include raising structures out of flood prone areas, building dikes to keep water out of low-lying areas, avoiding placement of new structures in vulnerable areas and restoring wetlands to improve flood benefits to upland areas. In general, these adaptation measures will be planned and implemented by landowners.

business owners and local government officials to address projected impacts of sea level rise in a specific location. The Sea Level Rise Advisory Committee did not undertake any assessment of, or recommendations for, specific adaptation measures in Delaware. Rather, it focused its work on understanding and making recommendations that will improve Delaware's adaptive capacity.

Adaptive capacity can be defined as the ability to adapt. As it relates to sea level rise, adaptive capacity is the ability of individuals or agencies to assess potential impacts and to select and implement appropriate adaptation measures. Adaptive capacity includes availability of data and information, availability of technical assistance, availability of funding, ability to cooperate and communicate, and ability to gain support for adaptation measures.

#### Recommendations for Preparing for Sea Level Rise

Delaware's Sea Level Rise Advisory Committee was charged with developing recommendations for adapting the state to the likely impacts of sea level rise. Because sea level rise adaptation will occur at many different geographic levels, from an individual home to regional transportation networks, the advisory committee focused its efforts on researching and developing recommendations that will build the state's capacity to adapt, rather than pinpointing adaptation measures that should be used in specific locations. Over 100 separate options and seven objectives were developed by the advisory committee. After further research and discussion, the list was narrowed and released to the public for review at a series of public engagement sessions.

After review of public comments and additional investigation and discussion, the Sea Level Rise Advisory Committee formally approved the following recommendations for adapting to sea level rise:

<sup>&</sup>lt;sup>5</sup> As referenced from Mean Higher High Water (MHHW).

<sup>&</sup>lt;sup>6</sup>These impacts are fully described in Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware. Available online: http://de.gov/slrva

Objective 1: Improve Communication and Coordination among State, Federal, Local and Regional Partners to Streamline Sea Level Rise Adaptation Efforts.

#### Recommendations:

- 1.1 Improve coordination of permit decisions for adaptation projects among federal, state and local officials.
- 1.2 Create new partnerships to increase resources for research and development of adaptation options.
- 1.3 Increase opportunities for technology transfers and regional coordination for transportation issues affected by sea level rise
- 1.4 Incorporate sea level rise into public and private sector regional planning efforts.
- 1.5 Provide sea level rise information to the Delaware Agricultural Land Preservation Program.
- 1.6 Provide technical assistance to Delaware's Open Space Council for incorporating sea level rise into its criteria for acquisition of natural areas.
- 1.7 Conduct a comprehensive inventory of key funding, coordination, regulations and policies and analyze them for barriers and opportunities for sea level rise adaptation.

Objective 2: Provide Increased Regulatory Flexibility for Adaptation and Improve Consistency among Regulatory Agency Decisions.

#### Recommendations:

 Provide regulatory incentives that encourage sea level rise adaptation and that allow for innovative projects.

- 2.2 Encourage the governor to sign an executive order that would direct state agencies to plan for sea level rise.
- 2.3 Conduct a comprehensive update to the state's regulatory tidal wetlands maps and provide a way to periodically update the maps to reflect changes occurring from sea level rise
- 2.4 Consider sea level rise implications in future regulatory updates for septic systems and wells.
- 2.5 Facilitate the connection of individual septic systems to community wastewater treatment systems with excess capacity when human safety and welfare are at risk.
- Consider sea level rise implications in future updates to the state Coastal Zone Act regulations,

Objective 3: Provide Consistent and Predictable Policies for Future Growth, Investment, and Natural Resource Management.

#### Recommendations:

- Incorporate sea level rise considerations into the Strategies for State Policies and Spending.
- 3.2 Consider incorporation of sea level rise considerations into municipal and county comprehensive development plans.
- 3.3 Consider use of a Transfer of Development Rights tool to direct future growth away from vulnerable areas.
- 3.4 Incorporate sea level rise into Delaware's Long Range Transportation Plan.
- 3.5 Incorporate sea level rise into the Transportation Operations Management Plan.

- 3.6 Encourage inclusion of sea level rise in Transportation Project Design Manuals.
- 3.7 Develop a dike safety program.
- 3.8 Develop a framework for decision-making regarding land protection and restoration strategies based on habitat vulnerability, migration potential and relative importance in the regional landscape, historical significance or other key factors.
- 3.9 Develop a comprehensive wetlands restoration, protection and retreat strategy in response to sea level rise.
- 3.10 Continue efforts to re-evaluate management strategies for existing coastal impoundments.
- 3.11 Evaluate the benefits and risks of permitting privately owned coastal impoundments.
- 3.12 Designate shoreline zones for adaptation action.
- 3.13 Conduct a legal review for disinvestment of publically owned infrastructure and privately owned buildings.
- 3.14 Develop a statewide retreat plan and update it periodically.

#### Objective 4: Increase Public Awareness of Sea Level Rise through Education, Outreach and Marketing.

#### Recommendations:

- 4.1 Develop a comprehensive outreach strategy to educate all stakeholders about sea level rise.
- 4.2 Provide education and outreach for impacted communities and citizens.
- 4.3 Improve the ability of homebuyers to investigate a property's potential vulnerability to sea level prior to purchase.

4.4 Provide targeted outreach to water and wastewater operators and water utilities.

# Objective 5: Improve the Availability & Robustness of Sea Level Rise Data Sets.

#### Recommendations:

- 5.1 Improve monitoring of current sea level conditions and improve predictions for timing of inundation.
- 5.2 Install additional water level and salinity observational stations in Delaware's tidal waters
- 5.3 Improve the accuracy of Delaware's elevation benchmark network.
- 5.4 Continue and expand studies regarding sediment accretion rates and susceptibility of wetlands to sea level rise.
- 5.5 Conduct research to better understand human response to sea level rise and adaptation.
- 5.6 Develop sea level models that incorporate storm surge impacts.
- 5.7 Conduct a risk assessment for Delaware's system of dikes & levees.
- 5.8 Encourage federal agencies to integrate sea level rise planning into their flood
- Model potential stormwater inundation problems in highly vulnerable areas.
- 5.10 Develop a model that will predict changes to salinity in surface water that may occur under differing sea level rise scenarios
- 5.11 Develop a statewide groundwater model.
- 5.12 Develop and maintain a comprehensive database that contains the location and condition of all wastewater infrastructures.

- Identify and preserve areas for potential wetland migration.
- 5.14 Identify the data necessary to plan transportation investments.
- 5.15 Increase understanding of the regional implications of loss of industrial areas in coastal Delaware.
- 5.16 Improve understanding of impacts to adjacent properties from adaptation actions.
- 5.17 Encourage the development of a research and policy center at a university or college campus that would focus on applied research for sea level rise and adaptation.
- 5.18 Foster pilot projects that demonstrate the effectiveness of best management practices for management of agricultural lands affected by sea level rise.

# Objective 6: Provide Technical Assistance to Partners for Assessing Vulnerability and Choosing Adaptation Strategies.

#### Recommendations:

- Create a coordinated effort to provide technical assistance to local governments.
- 6.2 Provide land managers, fisheries managers and farmers with the information and extension support necessary to manage lands and fisheries in areas affected by sea level rise.
- 6.3 Provide technical assistance for industrial and port facilities to incorporate sea level rise into investment plans and continuity of business plans.
- 6.4 Develop best management practice manuals for adaptation in Delaware.

6.5 Develop a database of costs of adaptation options for use by decision-makers and the public.

# Objective 7: Expand Funding Opportunities for Adaptation Planning and Implementation Projects.

7.1 Convene an expert panel to provide an assessment and analysis of funding options for adaptation measures.

#### Adaptation in Delaware is Already Underway

Although formal recommendations for adapting to sea level rise are new, sea level rise adaptation is already occurring in Delaware. The state has routinely replenished publicly accessible beaches on the Atlantic Ocean and Delaware Bay coasts for decades. It has a robust land acquisition program and a statewide land-use regulation for coastal areas. It also requires counties and municipalities to plan for the future through comprehensive development plans. At a local level, at least seven municipal governments are actively planning for the future effects of sea level rise and storm surge with assistance from DNREC and Delaware Sea Grant College Program. These on-the-ground adaptation efforts will continue in parallel with implementation of the 55 recommendations listed above.

#### **Guiding Principles for Adaptation**

During the development of adaptation recommendations, the advisory committee had a number of discussions about how adaptation decisions should be made. For example, concerns were expressed about whether adaptation measures implemented in one location could have a negative impact on surrounding locations. Concerns were also expressed about how adaptation actions would be prioritized for state funding.

As a result of those discussions, the advisory committee has compiled the following "Guiding Principles for Adaptation." These principles should

be taken into consideration during the planning and implementation of on-the-ground adaptation projects:

- Begin adaptation planning and implementation: adjust and make improvements as more information becomes available.
- Avoid unnecessarily prescriptive adaptation actions: empower decisions at the local level.
- Incorporate adaptation into existing programs and mechanisms, so as to not create a new bureaucracy.
- Engage broad public participation in adaptation decisions.
- Use the best available science and technology for decision-making and adaptation actions.
- Coordinate and consider consequences of adaptation among jurisdictions and among resource types.
- Strike a balance between protection of homes, infrastructure and conservation of natural resources.
- Strive for equity in selection and funding of adaptation measures:
  - Consider impacts to environmental justice communities,
  - Consider trade-offs between adaptation projects up-state and downstate.
- Encourage development of funding mechanisms for adaptation based on fairness, equity and justice for all citizens.
  - Public investment in sea level rise adaptation should be directed toward endeavors that benefit the most citizens as possible.

- Public investment in sea level rise adaptation should be considered and weighed against the many needs of Delaware's citizens.
- Fee based funding options, if developed, should be user-related (such as motor fuel taxes that pay for roadway maintenance).

#### Next Steps

At its final meeting, Delaware's Sea Level Rise Advisory Committee presented these recommendations to the Secretary of the Delaware Department of Natural Resources and Environmental Control, marking the completion of the advisory committee's work. This event also represented the start of efforts to put the recommendations into place, a process that will take many years.

The DNREC Delaware Coastal Programs has committed to coordinating efforts to implement the recommendations for adapting to sea level rise, working in collaboration with state agencies, local and county governments, non-governmental organizations, educators, businesses and citizens. Some recommendations can be implemented quickly and with little new funding; others may take significant additional funding, time and coordination. A workshop will be held in 2014 that will bring together potential partners to prioritize recommendations for implementation and to compile additional information about the steps necessary to implement each recommendation.

Adaptation planning and selection of adaptation measures at the parcel, local or agency level can occur in parallel to state efforts to implement the 55 recommendations of the Sea Level Rise Advisory Committee. Although implementation of the recommendations will improve Delaware's ability to adapt in the future, technical assistance and grant funds are available now from a variety of sources to assist those wishing to proactively address sea level rise and prepare for tomorrow's high tide.

## **Chapter 1: Introduction**

Delaware's Sea Level Rise Advisory Committee

Delaware's economy and quality of life are linked to its shores, its vast expanses of tidal wetlands and its fertile farm fields. Because of its location, low average elevation and dependence upon coastal resources for jobs and recreation, Delaware is particularly vulnerable to the effects sea level rise, including loss of low-lying land and structures, saltwater intrusion into groundwater and surface water and increased coastal flooding during storm events.

Delaware's Sea Level Rise Advisory Committee was established to investigate the state's vulnerability to sea level rise and to provide recommendations about how to best prepare for higher sea levels. The Committee was convened in November 2010 by invitation of Collin O'Mara, Secretary of the Delaware Department of Natural Resources and Environmental Control (DNREC). The advisory committee is composed of members from a wide variety of stakeholder groups including state agencies, local governments, citizen organizations, business organizations and environmental organizations.

The publication of "Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware" marks the completion of the advisory committee's work. The central component of this document is a list and description of 55 recommendations for adapting to sea level rise in Delaware. These recommendations focus on building the necessary capacity for Delaware agencies, local governments, businesses and individuals to plan for and put into place strategies for responding to sea level rise.

The advisory committee met its first milestone in July 2012 with the publication of "Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability for the State of Delaware." This document and its appendices provide an exhaustive accounting of resources vulnerable to sea level rise of up to 1.5 meters (4.9 feet) in Delaware. It also identifies a set of resources that are of the most concern statewide.

The publication of this document, "Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware," marks the completion of nearly three years of work by the advisory committee and DNREC staff. Its central component is a list and description of recommendations for adapting to sea level rise in Delaware. These recommendations were

#### **Advisory Committee Goal**

The goal of Delaware's Sea Level Rise Advisory Committee is "to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, business practices and make informed decisions."

developed through an extensive stakeholder and public process. The document also contains a set of guiding principles, developed by the advisory committee for use as decision-making criteria and background information about adaptation and adaptation strategies.

#### Sea Level is Rising

Sea level rise is occurring today, both locally and across the globe. Globally, sea levels rise for two primary reasons: (1) expansion of saltwater as it warms, and (2) loss of ice on land. As the ocean absorbs solar radiation in excess of what it emits. the water warms. When water warms, it expands and causes the average level of the water to rise. In addition, as Earth becomes warmer, land-based glaciers and ice sheets melt and slide into the sea. This melt-water and ice empties into oceans and cause the average level of the water to rise. In combination, these two processes constitute the eustatic (or global) rate of sea level rise. The eustatic sea level rate during the twentieth century, as determined by tide gauge measurements, was about 0.07 inches per year (or about 7 inches over 100 years) (Bindoff, et. al., 2007).

Tide gauges indicate that the increase in local mean sea level<sup>8</sup> in Delaware is greater than the

increase in eustatic sea level. The sea level rise trend recorded at the tide gauge in Lewes is 0,13 inches per year (or 13 inches over 100 years), as compared to the eustatic trend of 0.07 inches per year. This difference is due to the vertical movement of Earth's crust which is causing the land in Delaware to slowly sink. Tide gauges record this combined motion of the land and the



Members and Alternates of the Sea Level Rise Advisory Committee from left to hight lst Row: Lew Killmer, Sarah Cooksey, Karen Weldin Slewart, Lorlice Harrison, Constance Holland, Buth Ann Jones, Kerwi Whitteker, Gerdal Kauffmen, Mary Ellen Gray, Pamela Bakerian, Rich Collins, Victor Letonoff. 2nd Row Richard Perkins, Barbara DeHawen, Chris Semmerfold, William Lucis, Don Ricox, Jenaifer Adkins, Rob McCleary, John Taylor, Branna Gogin, Hol Gedwin. Not pretured: Guilton Johnson, Marcus Honry, Jeff Shockley, Richard Jones, Mirchael Kirkpatrick, Mark Davis.

### Sea Level Rise Advisory Committee Member Agencies

Delaware Association of Realtors

Delaware Chamber of Commerce

Delaware Department of Agriculture Delaware Department of Health and Social Services

Delaware Department of Natural Resources and

Environmental Control

Delaware Department of Safety and Homeland Security

Delaware Department of Transportation

Delaware Economic Development Office Delaware Farm Bureau

Delaware Insurance Commissioner's Office Delaware League of Local Governments

Delaware Legislature

Delaware Nature Society

Delaware Office of the Governor

Delaware Office of Management and Budget Home Builders Association of Delaware

Kent County

League of Women Voters of Delaware The Nature Conservancy

New Castle County

Positive Growth Alliance Sussex County Tidewater Utilities, Inc.

University of Delaware

Local Mean Saa Level is a term that describes the height of the ocean relative to fand, measured hourly by a tide gauge and averaged over a nineteen year period known as the National Tidal Datum Epoch.

sea. Figure 1 shows the local mean sea level trend from the tide gauge at Lewes from 1919 to 2012. Other tide gauges throughout the Mid-Atlantic show similar trends<sup>9</sup>.

While it cannot be known with certainty, climatologists have predicted that the rate of sea level rise occurring today will likely become greater in the decades to come (Williams et al., 2009). The extent of the increase will depend on a number of factors including future emissions of greenhouse gases (especially carbon dioxide), the rate at which the temperature of the ocean increases and the rate at which ice is lost from land-based glaciers.

In 2009, a Sea Level Rise Technical Workgroup was formed to provide DNREC with planning scenarios for sea level rise to the year 2100. This workgroup, composed of scientists from the University of Delaware, Delaware Geological Survey, Center for the Inland Bays, Partnership for the Delaware Estuary and DNREC, reviewed historical data for local sea level rise and findings of international and national sea level rise expert panels. Based

on this information, the technical workgroup recommended three planning scenarios for sea level rise which were then reviewed by national experts¹o and used by DNREC in the development of an internal policy that directed it to plan for sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009).

The technical workgroup chose to recommend a range of scenarios to DNREC because it is not possible to precisely predict future rates of sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009). The three scenarios can be used as a planning tool to determine a range of potential outcomes and options. The technical workgroup's scenarios were 0.5 meters (1.6 feet), 1.0 meter (3.3 feet), and 1.5 meters (4.9 feet) of sea level rise between now and 2100 based upon low, moderate and high estimates of future global warming rates, respectively. Figure 2 contains a graph of the three scenarios, which can be used to estimate a range of sea level rise scenarios for years between now and 2100. The upward curvature of the lines indicates that the rates increase with time. The

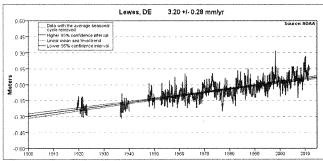


Figure 1. Local mean sea level trend at Lewes (NOAA, 2013).

<sup>&</sup>lt;sup>9</sup> Tide gauge information is available from the National Oceanic and Atmospheric Administration: http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml

<sup>&</sup>lt;sup>10</sup> The scenarios were reviewed by S, Jeffress Williams, Coastal Marine Geologist at the US Geological Survey Woods Hole Science Center and Jim Titus, US Environmental Protection Agency

"stable," line is included for reference; it shows the sea level that would occur in Delaware if the past century's average rate of sea level rise continued into the future, rather than accelerating.

These three scenarios were provided to the Sea Level Rise Advisory Committee by DNREC and were used to assess resource vulnerability to sea level rise!". Evaluation and endorsement of these recommended sea level rise scenarios was outside of the purview of the advisory committee.

It is important to note that scientists are continually working to increase their knowledge about sea level rise and to provide better predictions of future sea levels. As new data and information become available, the planning scenarios will be revised in order to reevaluate potential impacts.

# Delaware's Vulnerability to Sea Level Rise

Delaware's low average elevation makes it particularly vulnerable to the effects of rising sea levels, which include loss of low-lying land and structures, saltwater intrusion into groundwater and surface water and increased coastal flooding during storm events. Each of these impacts also has secondary social, economic and environmental effects. The Sea Level Rise Vulnerability Assessment for the State of Delaware found that sea level rise would have direct impacts statewide,

including all three counties and 31 municipalities. The report also found that under the three planning scenarios described above, between 8% and 11% of Delaware's total current land area could be inundated at high tide 2 by the year 2100 (DNREC, 2012).

Of the 79 resources studied in the state's vulnerability assessment, the advisory committee ranked 16 as high concern statewide and six as moderate concern statewide (DNREC, 2012). Potential impacts from sea level rise for each high and moderate concern resource are briefly described below:

#### High Concern Resources

#### Beaches and Dunes

Delaware's coastline is an important ecological resource and economic driver for the state. Shore-lines naturally shift and retreat in response to wind, waves, tides, storms and rising seas. Sea level rise can exacerbate shoreline erosion, further damaging dune habitat and leaving infrastructure along the coastline more vulnerable to storm damage. Beach replenishment has been the predominant means to offset sand loss and protect structures. Due to the economic value, natural resource value and significant state investment in sand replenishment, this resource was ranked as a high concern.

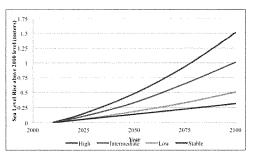


Figure 2. DNREC sea level use planning scenarios (DNREC Sea Level Rise Technical Workgroup, 2009)

An interactive map of these scenarios is available online: http://de.gov/sirmap.
 As measured by Mean Higher High Water

#### Coastal Impoundments

Coastal impoundments are managed wetlands that provide important habitat for a variety of birds and fish. Impoundments in each county are at risk from sea level rise. A sea level rise of 0.5 meters (1.6 feet) would result in the potential inundation of 81% of the state's acreage of impounded wetlands. Up to 99% of all the state's acreage of impounded wetlands could be inundated at both 1.0 meters (3.3 feet) and 1.5 meters (4.9 feet) of sea level rise. Since the majority of coastal impoundments within the state may be affected, this resource was ranked as a high concern.

#### Dams, Dikes and Levees

Between 39% and 78% of the state's 50 miles of dams, dikes and levees could be inundated by sea level rise by 2100. If a breach or structural failure were to occur, the resultant flooding could affect a large area inland of the structure. The highest concentration of potentially affected dikes is in Kent County, whose dikes primarily protect wildlife areas. In New Castle County, the acreage of potentially impacted dikes is fewer, however the potential damage from failure is greater as the majority of these dikes protect people, property, roadways and, in one case, a contaminated site. Due to these considerations, inundation of dams, dikes, and levees in the state was ranked as a high concern.



A snowy egret forages in a man-raade impoundment of Bornbay Hook National Wildlife Reluge. The majority of these impoundments in the steel, which provide unique habitat and recreational opportunities, are at tisk from the effects of sea level rise.



These maps depict mean higher-high water (MHHW) in Bowers Beach Delaware under the three planning scenarios for sea level rise. Blue represents MHHW today, giesen is MHHW with 0.5 meter of sea level rise; to the sea level rise; the sea

#### **Evacuation Routes**

Between 1% and 6% of the state's 1,185 miles of designated evacuation routes could be inundated by sea level rise by 2100. As with any roadway, a small area of inundation can cause an entire roadway segment to become unusable. Because evacuations rely on automobile transportation and even small segments of flooded roadways can prevent or slow evacuation by car, inundation of evacuation routes was ranked as a high concern.

#### Freshwater Tidal Wetlands

Freshwater tidal wetlands occur at the upper reaches of estuaries and are home to unique plant and animal communities. Sea level rise could impact between 84% and 98% of the total freshwater tidal wetland acreage statewide by the year 2100, replacing freshwater tidal marshes with brackish marshes or open water and causing major shifts in species composition. Because of the unique habitats contained within freshwater tidal wetlands and because the majority of the resource within the state could be affected, this resource was ranked as a high concern.

#### Future Development Areas

Between 3% and 7% of land designated as future development areas by Delaware's Strategies for State Policies and Spending are within an area that could be inundated by sea level rise by 2100. These areas are typically rural or suburban in nature and are adjacent to the actively growing zones of Delaware's municipalities. Four-fifths of these potentially inundated areas are located in Sussex County and could be developed to meet the future demand for residential and commercial development in and around the resort areas. Due to the significant potential effects for development in Sussex County, coupled with the potential need for state funding of infrastructure repairs statewide, sea level rise within future development areas was ranked as a high concern.

## Habitats of Conservation Concern

Habitats of Conservation Concern are habitats identified in the Delaware Wildlife Action plan as having special significance in Delaware, as being particularly sensitive to disturbance, and/or having a high diversity of rare plants. Between 55% and 65% of the total acreage of the 15 Habitats

of Conservation Concern analyzed could be inundated by sea level rise by 2100. Because these exceptional habitat types often harbor rare plant and animal species and are sensitive to environmental stresses, including sea level rise, this resource was ranked as a high concern.

#### Heavy Industrial Areas

Between 16% and 25% of the acreage of heavy industrial lands in the coastal area (as permitted by Delaware's Coastal Zone Act) are within an area that could be inundated by sea level rise by 2100; the majority of these areas are in New Castle County. If the lands currently zoned for heavy industry become unsuitable for industrial operations, retaining these businesses within the state could prove difficult due to the lack of suitable industrially zoned land and the difficulties of rezoning land to industrial uses. Due to the significant potential statewide effects resulting from sea level rise, heavy industrial areas were ranked as a high concern.

#### Port of Wilmington

Between 36% and 73% of the Port of Wilmington's property is within an area that could be inundated by sea level rise by 2100. The port is based in northern New Castle County; however, its economic value to Delaware and the entire northeast region makes



The Red Lion Dike, which protects a contaminated former industrial sits from flood waters, is one of several dikes in New Cestle County that will be repaired starting in 2013 Flooding of industrial land as a result of storm surge and see level rise could cause contaminant selected so the contaminant selected so that the contaminant selected se

exposure to sea level rise a state and regional issue. Due to these considerations, inundation of the Port of Wilmington was ranked as a high concern.

#### Protected Lands Statewide

Protected lands encompass a variety of lands owned by state, local and municipal governments, conservation groups and individuals, including state wildlife areas and parks, historical sites, national wildlife refuges, recreational facilities and conservation easements. Between 37% and 44% of these lands are exposed to sea level rise under the three scenarios. Because these lands represent a significant investment to protect natural habitats and recreational use and because sea level rise could impact their intended use, protected lands were ranked as a high concern.

### Roads and Bridges

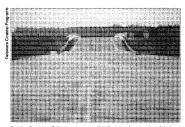
Between 1% and 5% of the state's 8,990 miles of roads and bridges are within an area that could be inundated by sea level rise by 2100. The highest concentration of roadway exposure was found in Sussex County; however, potential exposure was found throughout the state. Due to the potential regional impacts, inundation of roads and bridges from sea level rise was ranked as a high concern.

#### Railroad Lines

Between 2% and 6% of the state's railroad lines are within areas that could be inundated by sea level rise by 2100. While the majority of the potential impact is within New Castle County, if a single rail line segment becomes inundated, the functionality of the entire line could be lost. Because disruption of rail service in Delaware could have impacts throughout the state and region, inundation of railroad lines as a result of sea level rise was ranked as a high concern.

#### Tidal Wetlands

Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Up to 97% of the state's tidal wetlands could be impacted at the 0.5 meter (1.6 feet) scenario, and 99% at both the 1.0 meter (3.3 feet) and 1.5 meter (4.9 feet) scenarios. Since



Route 9 near Odessa frequently floods during the highest tides of each month. Increasing sea levels will place more of Delaware's roadways at risk of flooding during high tides and storm starges.

the majority of the resource within the state may be affected, impacts to tidal wetlands as a result of sea level rise were ranked as a high concern.

#### Tourism and Coastal Recreation

Tourism and coastal recreation are important components of Delaware's economy and quality of life. Delaware's public beaches, a significant tourism asset, are currently replenished on a routine basis with federal and state funding. Accelerated rates of sea level rise may necessitate larger or more frequent beach replenishment projects to preserve recreational beach uses. Due to the potential for revenue losses statewide, coupled with the potential increased funding needs for maintenance or repair of tourist destinations, sea level rise impacts to tourism and coastal recreation was ranked as a high concern.

#### U.S. Fish and Wildlife Service Refuges

Delaware has two National Wildlife Refuges; Prime Hook in Milton and Bombay Hook near Smyrna. Area residents and tourists use the refuges for outdoor recreation activities such as hunting, fishing, birding, and wildlife watching. Refuge wetlands provide extensive habitat for numerous species. Between 85% and 95% of refuge acreage could be inundated under the three scenarios for sea level rise. While the impacts are localized, the acreage affected (21,354 to 24,120 acres) represents a significant loss of protected habitat and was ranked as a high concern.

#### Wells

Residents and businesses in Kent and Sussex Counties rely on groundwater resources for drinking, irrigation and industrial purposes. Sea level rise can compromise wells through inundation or through saltwater intrusion that can contaminate drinking water. Statewide, between 3% and 7% of domestic wells, 3% and 7% of industrial wells, 1% and 2% of irrigation wells, and 2% and 10% of public wells are within areas that could be inundated by sea level rise by 2100. Because access to clean water is a necessity and demand on inland wells may increase, sea level rise impacts to wells was ranked as a high concern.

#### **Moderate Concern Resources**

Agricultural Land Conservation Easements

Agricultural land conservation easements provide agricultural lands with permanent protection from development in order to maintain agricultural activities. Statewide, 13% to 17% of the land in agricultural conservation easements is within areas that could be inundated by sea level rise by 2100. The impact is primarily in Kent County. Conservation easements are considered to be an important tool to preserve farming operations and were ranked as a moderate concern.

#### Landfills

Between 1% and 3% of landfill acreage (including salvage yards, dumps and industrial landfills) in the state are within areas that could be inundated by sea level rise by 2100. However, no currently operating municipal landfills would be inundated under the three scenarios for sea level rise. Due to the likely difficulty of relocating impacted sites and because of potential for contaminant migration, inundation of landfills was ranked as a moderate concern.

#### Nature Preserves

Nature preserves are relatively undisturbed protected lands that represent some of Delaware's most important natural habitats. The percentage of affected acreage of dedicated nature preserves ranges from 34% to 43% under the three scenarios for sea level rise. The impact to nature preserves is local in scale; however, the habitat value of those sites may be exceptional. As a result of these fac-



DNREC scientists collect samples of tidal wetland sediment to determine wetland resiliency to increasing set levels. Modeling of sea level is endicates that dimed all of Delaward's lidal wetlands will be inundated by sea level is eit fit by cannot accrete enough sediment to keep pace vertically.

tors, impacts to nature preserves from sea level rise were ranked as a moderate concern.

#### Residential Areas

Statewide, 1% to 5% of the 346,000 residences in Delaware are within areas that could be inundated by sea level rise by 2100. The highest concentration of potentially affected homes is in Sussex County along the barrier island south of Bethany Beach and around the Inland Bays. Additionally, residences within small coastal towns in Kent County are at risk of inundation from sea level rise, as are homes in the cities of Willmington, New Castle, and Delaware City. Because potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to residential addresses were ranked as a moderate concern.

#### Septic Systems

Statewide, between 1% and 4% of septic systems are within areas that could be inundated by sea level rise by 2100. The highest concentration of potentially affected septic systems is in Sussex County, particularly around the Inland Bays. The functionality of septic systems may be reduced as a result of rising water tables in addition to inundation. This may result in significant environmental and public health issues related to groundwater and resultant surface water contamination. Since potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to septic systems were ranked as a moderate concern.

Wastewater Facilities
Statewide, between 7% and 21% of sewer pumping stations, up to 17% of spray irrigation fields, and up to 13% of public treatment and collection facilities are within areas that could be inundated by sea level rise by 2100. The majority of this exposure is focused within eastern Sussex County; however, New Castle and Kent Counties have wastewater facilities that could also be affected. Because of the statewide implications for clean water and public health, inundation of wastewater facilities was ranked as a moderate

#### Planning Early for Sea Level Rise is Important

In past decades, sea level rise has rarely been considered by governments, organizations and individuals when making decisions about where to develop, how to build or what lands to preserve for future generations. However, consideration of sea level rise in these decisions is important because changes in sea levels can impact the longevity, safety, and return on investment of projects that have long planning horizons or long life-spans. Improved tools, information and training are now available for those wishing to begin planning and adapting to sea level rise.

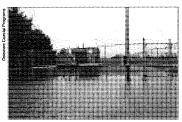
In a broad sense, adaptation can be defined as "adjusting" to new conditions by taking steps to moderate and cope with the effects of sea lev-el rise (Levina & Tirpak, 2006). These steps can be planned and implemented at a variety of geo-graphic levels, and by a variety of stakeholders. In Delaware and in many other locations, the process of adaptation involves two distinct efforts: (1) planning and implementing adaptation measures, and (2) building adaptive capacity.

#### Planning and Implementing Adaptation Measures

Adaptation measures can be defined as on-theground actions that can be taken to prepare for sea level rise in a particular location. They include raising buildings above flood prone areas, building dikes, and restoring wetlands. These measures are



These row homes in the neighborhood of Southbridge in the City of Wilmington experience frequent flooding and are within a mapped sed level rise area. Sed level rise may have a disproportionate impact on minerity and low-income communities like Southbridge.



Flood waters reach the edge of a pumping station facility in Bowers Beach during a noreaster in November 2009. Pumping stations like this one are necessary to tramport water to regional treatment facilities, flooding from coast-al storms and see level is see an affect their operations and cause public health impacts.

described in more detail in Chapter 2 of this document. In general, these adaptation measures will be planned and implemented by landowners. business owners and local government officials to address projected impacts of sea level rise in a particular geographic location (a specific shoreline, park or roadway). The Sea Level Rise Advisory Committee did not undertake any assessment of, or recommendations for, specific adaptation measures in Delaware. Rather, it focused its work on understanding and making recommendations that will improve Delaware's adaptive capacity.

Building Adaptive Capacity
Adaptive capacity can be defined as the ability
to adapt (Levina & Tirpak, 2006). As it relates to planning for sea level rise, adaptive capacity is the ability of individuals or agencies to assess potential impacts of sea level rise and to select and implement appropriate adaptation measures. Adaptive capacity includes the following, among many others:

- · Availability of data and information necessary to plan successful adaptation measures
- Availability and level of technical knowledge and skills by those planning adaptation measures
- · Availability of technical assistance
- Availability of funding to implement adaptation measures
- · Existence of laws and regulations that do not impede implementation of adaptation measures
- · Availability of information about the economic impact of adaptation measures
- Ability to cooperate and coordinate among jurisdictions
- Ability to gain public support for adaptation measures

While Delaware enjoys a high level of support for proactive planning for sea level rise (Responsive Management, 2010) and is among the first states to comprehensively plan for sea level rise at a statewide level, many barriers to adaptation still exist.

#### Recommendations for Adapting to Sea Level Rise in Delaware

Over a period of nearly three years, the Delaware Sea Level Rise Advisory Committee assessed the state's vulnerability to sea level rise, investigated adaptation options, developed objectives and approved recommendations aimed at improving the ability of Delaware's citizens, business owners, local governments and state agencies to make well-informed adaptation choices. More than one-hundred ideas for building capacity were considered by the advisory committee, with 55 ultimately approved as recommendations for inclusion in this report. These objectives and recommendations are fully described in Chapter 6. In addition, a set of guiding principles for implementing adaptation measures was also developed; these are outlined in Chapter 3 of this document.

The background information and recommendations contained in this document are intended to provide a roadmap for improving Delaware's ability to adapt to sea level rise in the coming decades Implementation of these recommendations will require the continued dedication, cooperation, and coordination of citizens, elected officials, government agencies and non-governmental agencies. Chapter 7 outlines the next steps for implementing these recommendations. Implementation of these recommendations will build the adaptive capacity necessary to improve community resiliency for coastal storm impacts, foster wise use of public funding, lead to responsible siting of facilities and infrastructure and promote sustainable natural habitats.

# Chapter 2: Adaptation Strategies and Measures

This chapter provides background information about adaptation strategies and specific adaptation measures that can be implemented by individuals or agencies in preparation for sea level rise. While the Sea Level Rise Advisory Committee has not recommended strategies or measures for any specific location, an understanding of the range of options available for adapting to sea level rise is helpful for understanding the rationale behind the 55 recommendations for preparing for sea level rise presented in Chapter 6.

#### **Adaptation Strategies**

Adaptation strategies are on-the-ground actions that can be taken to prepare for or respond to sea level rise in a specific location. There are four general categories of adaptation strategies: avoid, accommodate, protect, and retreat. Within each category are numerous measures that can be taken alone or in combination. The planning and selection of adaptation strategies will be done by individuals, business-owners and communities and will be dependent upon local conditions, funding availability and community support.

Each of the four adaptation strategies is described below, with a description of the types of measures that can be taken. This list is not exhaustive, as many very good references are widely available for those wanting more information. In addition, Appendix H: Resources for Adaptation, provides a listing of tools, funding and technical assistance to those wishing to plan and select adaptation strategies.

#### Avoid

Avoidance adaptation strategies seek to limit new development or infrastructure in areas that are particularly vulnerable to sea level rise by

redirecting development to less vulnerable areas (Deyle et al., 2007). Applying avoidance strategies in Delaware can help minimize liability in areas that can be impacted by sea level rise, potentially decreasing negative impacts to homes, businesses and infrastructure, while maintaining certain land uses. Some of these strategies can also allow for protected wetlands to naturally migrate landward in response to rising tides, permitting them to continue to provide natural buffers for the shoreline by absorbing the energy of storms and decreasing erosion (Bertness, 1999). These types of strategies can be implemented through transfer of development rights, conservation easements, setbacks, and other mechanisms (Deyle et al., 2007 and NOAA, 2010).

#### Transfer of Development Rights

Transfer of development rights (TDR) tools can be used by local governments to shift development trends to areas where development is more preferred. TDR tools "offer communities a potent tool for managing growth" (Williams-Derry & Cortes, 2011) by allowing landowners, in areas where development is less desired, to opt to sell their development rights and transfer them to

<sup>&</sup>lt;sup>13</sup> The Adaptation Tool Kit, published by the Georgetown Climate Center is one such reference document that is particularly useful for local governments. It is available online: http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use. For homeowners, he recently published Homeowners Handbook to Prepare for Natural Hazards is also very useful, It is also available online: http://deseagrant.org/products/2012-homeowners-handbook

areas where the local government would like to encourage development (Grannis, 2011). Properties in which the owner sold the development rights are then placed into conservation easements to preserve the land in perpetuity. Both Kent County and New Castle County have established TDR ordinances for the purpose of helping to direct growth.

#### Conservation Easements

Conservation easements are voluntary landowner agreements that establish deed restrictions on land to prevent future development and are instrumental in maintaining open space. These preserved open spaces help reduce flooding and stormwater runoff, and can promote groundwater recharge. They can also allow for future wetland migration necessary to accommodate sea level rise (NOAA, 2010 and Titus & Craghan, 2009). Land preservation organizations in New York and Maryland have easements creating buffers specifically for allowing wetlands and beaches to naturally migrate landward (Titus & Craghan, 2009).

#### Setbacks

Setbacks are state, county or local regulations that can direct new development away from areas that experience impacts from inundation, beach erosion, and advancing coastal flood boundaries (Titus & Caghan, 2009 and Deyle et al., 2007). These regulations require development to be constructed a distance from the shore; either by a set distance or by an established multiple of the

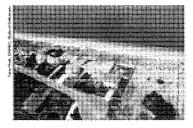
annual average erosion rate (Deyle et al., 2007). For example, "North Carolina requires new structures to be set back from the primary dune based on the current erosion rate times 30 years for easily moveable homes, or 60 years for large immovable structures (Titus & Craghan, 2009)."

#### Accommodate

Accommodation strategies acknowledge the longterm effects of sea level rise to an area, while implementing short-term measures to maintain the existing use (CSA International, 2008 and Boateng, 2008). These strategies decrease the risks of sea level rise impacts without employing potentially more costly protection strategies (Boateng, 2008). Examples of accommodation strategies include elevating a structure, drainage modifications, green infrastructure, and floodgates (Boateng, 2008 and Titus & Craghan, 2009), among others.

#### Elevation

Elevating structures involves raising a building's foundation to a level that accommodates for projections of increased flooding for the area over a specific time (Titus & Craghan, 2009). Elevation of a building can be implemented on an individual basis or as part of a comprehensive land use program for a local community. According to FEMA (2011), elevating a structure higher than the locally required lowest floor elevation provides additional protection against flood damage and can result in decreases in the cost of federal flood insurance.





The image on the left show houses that have been built set-back from the water. The image on the right illustrates homes with no set-back requirement Setbacks provide a natural buffer from erosion and storm surge, and protect houses and public infrastructure from these elements.

Elevating structures, public facilities, and associated infrastructure, may be more cost effective than other adaptation strategies and should be considered after a site specific cost benefit analysis is conducted (CSA International, 2008).

#### Green Infrastructure

Green infrastructure projects use a natural means to address secondary impacts associated with development, such as stormwater management. These projects include drainage systems that incorporate bioswales, rain gardens, and naturally designed water retention ponds to hold and treat stormwater (Hamin & Gurran, 2008). Local communities can take steps to incorporate green infrastructure into projects to increase flood storage capacity and to avoid overwhelming combined storm and sewer overflows (Foster et al., 2011). Green infrastructure systems help provide many flood storage and water quality benefits, but may require large areas of open space that may not be available, or may be too costly to obtain (Hamin & Gurran, 2008).

#### Floodgates

Floodgates are moveable gates that span rivers to control water flow. They have been constructed throughout the United States, as well as in other areas of the world, to address storm surge and reduce flooding in areas prone to storm related flooding. These structures are built to span entire rivers and involve gates that are only lowered when storm surge is predicted to cause significant flooding to areas upstream of the gate. Titus and Craghan (2009) predict that as sea levels rise, the gates will need to be lowered on a more regular basis, which can impact havigation. These gates may be best suited for densely populated areas (Titus & Craghan, 2009 and CSA International, 2008).

#### Protect

Protection adaptation strategies focus on protecting land from inundation, erosion, or storm-induced flooding through the construction of various structures such as jettles, groins, living shorelines, bulkheads, and beach nourishment (Titus & Cragan, 2009). Construction of these structures helps preserve a static shoreline, which may provide a



Houses in areas that experience flooding can be raised to a height that allows for water to pass undermeth, reducing the tak of future flood damage to the situature from coastal storms and seal level rise. This image shows a home that has been retrofited to accommodate increasing flood levels in the area, while a neighbor's house is not elevated and remains at tak.



This rain garden at the St. Jones component of the Deiaware National Estuarine Research Reserve collects rain water that would otherwise flow into the St. Jones River. Rain gardens are planted with a variety of plants that are attractive, easy to care for provide wildlife habitat, and improve water quality by filtering out pollutants.

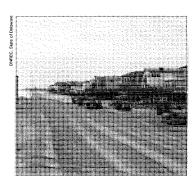
short-term solution to the long term impacts of sea level rise (NOAA, 2010). Many of these strategies are already commonly used in Delaware, including: periodic beach nourishment projects which have been successful in maintaining coastal beaches; bulkheads constructed by private homeowners to stabilize their properties; and dikes that protect public infrastructure, low lying communities, and environmentally sensitive areas. Hybrid approaches to protecting shorelines are also used to "retain some of the storm-resistance of a hard structure, while also maintaining some of the features of natural shorelines" (Titus & Cragan, 2009).

#### Beach Nourishment

As stated in Delaware Code (7 Del. C. § 6801), beaches are "valuable natural features which furnish recreational opportunity and provide storm protection for persons and property, as well as being an important economic resource for the people of the State." Regular protection of Delaware's beaches occurs through periodic placement of sand on the beach. The sand placed on the beach can be dredged from offshore sand deposits or brought in by truck from inland sources. These beach nourishment projects prevent or slow beach erosion and shoreline migration that are caused, in part, by sea level rise. "Beach erosion and shoreline migration occur due to the influence of waves, currents, tides, storms and rising sea level. These natural forces have created. and will continue to alter, the beaches of the State (7 Del. C. § 6801)." Erosion and shoreline migration can still occur on nourished beaches; the rate of erosion can be greatly impacted by coastal storms such as hurricanes and nor'easters. Sustaining a nourished beach and its dune system requires continuing maintenance through subsequent nourishment projects at regular intervals (NOAA, 2010), which comes at a significant cost that is usually paid for with public funds. Development on or adjacent to beaches should consider the natural forces impacting upon them and the dynamic nature of those natural features. A cost-benefit analysis of beach nourishment can guide management decisions to determine the long-term financial implications of this adaptation strategy.

#### Bulkheads

Bulkheads are vertical walls constructed along the shoreline that are designed to reduce erosion and to protect existing structures and the land upon which they are built (NOAA, 2010). Bulkheads can be effective for the water elevations that they are designed for but as sea levels rise, alternative solutions may need to be explored (Titus & Cragan, 2009). Decisions about siting and design of homes often "underestimate the extent and magnitude of actual flood hazards that a coastal building will experience over its lifetime" (FEMA, 2011). Therefore, protection measures like bulkheads may not be along-term solution for adapting to sea level rise.



A dune is constructed as part of the beach nourishment project in South Bethamy in 2007. Beach nourishment projects can protect homes and infrastructure from Rooding due to erosion and sea level rise while also maintaining the recreation-di uses of the shoreline residents and tourists.

#### Dikes

Dikes are elevated earthen or rock structures constructed parallel to a shoreline that prevent flooding and permanent inundation in the low-lying areas behind the structure (Titus & Cragan, 2009). These structures can be designed to include tide gates that manage the flow of water in and out of the low-lying areas behind the dike for storm protection and habitat purposes. To ensure continued protection, dikes must be inspected and maintained on a routine basis. Heights of many existing dikes in Delaware are not adequate to provide continued protection as sea levels rise, and a number of existing dikes in and around the City of New Castle have experienced significant erosion resulting from storms and poor maintenance (DNREC Delaware Coastal Programs, 2012). Due to the significant investments required, construction and maintenance of dikes can be cost prohibitive for some communities.

### Retreat

Retreat adaptation strategies allow for natural shoreline migration through land conservation and the removal of structures that prevent shore-

line movement (e.g. dikes, berms and bulkheads). These adaptation strategies may occur as an unplanned response after a severe storm or as a proactive response to avoid the long-term costs associated with increased impacts from sea level rise. For existing structures, retreat strategies are usually employed after other adaptation strategies have been found to be ineffective (Titus & Craghan, 2009). Retreat strategies include moving development out of harm's way through managed retreat, rolling easements, and land acquisition (Deyle et al., 2007; NOAA, 2010 and Titus & Craghan, 2009).

#### Managed Retreat

Managed retreat involves planning for projected increases in sea levels by relocating vulnerable buildings, infrastructure and public facilities before significant inundation occurs. Managed retreat was used to address erosion and sea level rise by the National Park Service when it relocated the Cape Hatteras Lighthouse inland in 1999; it has also been used in the relocation plan for recreational amenities at Surfer's Point in Ventura, California (CARA, 2006 and White et al., 2012). Managed retreat usually requires significant time to plan and implement, and also requires significant consideration of the economic and social impacts of relocating homes, businesses and public facilities (Titus & Craghan, 2009).

#### Rolling Easements

Rolling easements are used to ensure that coastal development does not interfere with the natural migration of shorelines as they move inland due to sea level rise. Rolling easements can be implemented in several ways, including development of state or local statutes, placement of conditions on development permits or voluntary agreements. These land use restrictions are usually developed with reference to a tide line, or other natural feature, which allow the feature to "dynamically fluctuate with natural coastal processes" (Grannis, 2011). Therefore, as the sea level rises and the natural feature moves, the associated development or land use restrictions "roll" inland and allow for natural shoreline erosion and wetland migration to occur (NOAA, 2010).

Rolling easements are used in Texas, Maine, Rhode Island, and South Carolina, where development permits are conditioned to include a clause to relocate a structure when erosion threatens the structure (Deyle et al., 2007). These easements, based on the Public Trust Doctrine, make intertical zones public lands, but "the doctrines vary substantially among the common laws of the individual states" (Deyle et al. 2007). While rolling easements may be



by A dike between the towns of Kesteren and Opheusden in the Northerlands is built to an elevation that protects home infrastructure to extreme flooding events on the Lower infrastructure to extreme flooding events on the Lower 2 km in the Northerland in the N



In 1870, the Carpe Hotteras Light Station in North Carollusz was approximately 1,500 feet away from the ocean. In the hundred years since, sforms, orosion, sea level rise, and other natural source caused shoreline migration that resulted in the lighthouse being just 157 feet from the ocean. In 1979, the Noticonal Parks Sorvice pursued a managed retreat stationary and moved the lighthouse and its outbuildings inland, where they are now safely 1,500 feet from the ocean (CARA. 2006)

less costly than measures that could achieve similar goals (e.g. land acquisition), easements would need to be established well before impacts occur to be effective.

#### Land Acquisition

Land acquisition by government entities, communities, businesses or not-for-profit organizations entails the purchase of vulnerable parcels for permanent protection and management, thereby allowing shoreline processes to occur naturally. Consent from the landowner to sell to the government or a conservation group is required for land acquisition programs. After purchase, the land can be managed as open space, public parks, or other passive infrastructure and is protected through conservation easements (NOAA, 2010; Titus & Craghan, 2009; and Grannis, 2011). Prioritization of properties for acquisition should include properties that have suffered severe repetitive losses due to storms; structures that are repeatedly damaged or destroyed; properties that have important habitats, such as wetlands, and are located in vulnerable areas; and properties where all other strategies are not cost effective to implement (e.g. elevating a structure) (NOAA, 2010). These programs can be an effective to implement (e.g. elevating a structure) of management away from vulnerable areas, but they do transfer management costs from the private property owner to the public (NOAA, 2010 and Titus & Craghan, 2009).

#### No Action

In addition to the four adaptation strategies described above, there is another option: no-action. A no-action strategy will be the default strategy for those who do not proactively plan ahead for future sea levels. By consciously or unconsciously choosing to not consider future sea level rise scenarios in planning and engineering design, decision-makers risk unintentionally pursuing a strategy of unplanned retreat. Unplanned retreat occurs when property, infrastructure and habitat losses from incremental erosion and inundation from sea level rise or a catastrophic flooding event are imminent or have already occurred, leaving few viable options for alternative protection, accommodation

or avoidance strategies. To minimize no-action strategies and its associated increased likelihood of unplanned retreat, the guiding principles for adaptation described in Chapter 3 encourage initiation of adaptation planning now, with adjustments to plans as new information becomes available.

## **Chapter 3: Adaptation in Practice**

This chapter provides information about the importance of planning for sea level rise and discusses the state's existing capacity to adapt. It also provides information about who should adapt to sea level rise and provides examples of how adaptation strategies may be implemented. Finally, this chapter provides a list of guiding principles that can be used in planning adaptation projects.

#### Proactive Planning for the Impacts of Sea Level Rise

The state's sea level rise scenarios provide information about potential high tide levels in 210014; a planning horizon of 87 years (DNREC Sea Level Rise Technical Workgroup, 2009). However, as outlined in the Sea Level Rise Vulnerability Assessment (DNREC Delaware Coastal Programs, 2012), the impacts from sea level rise will not be experienced all at once in 2100. These impacts will be seen and felt incrementally from today onward. Many of the Sea Level Rise Advisory

The Southbridge Marsh in Wilmington will be restored part of a plan to improve drainage and flood capacity in t area using green infrastructure techniques. Future sea lew will be considered in its final design.

Committee's recommendations for adapting to sea level rise highlight the need for improved accuracy and resolution of sea level rise projections that would make the planning scenarios more useful to current planning, homeownership and business cycles of 20 to 30 years. However, the sea level rise information available now provides the basis for a variety of stakeholders at all levels to begin

Proactive adaptation has many benefits. By incorporating future tidal levels into plans for new development and re-development, communities can achieve a high level of resiliency to today's coastal storm events while also minimizing the need for costly upgrades in the future. Incorporating future tidal levels into the design of new infrastructure also has similar benefits and may expand the lifespan of infrastructure such as roads and central sewer systems. In addition, many communities in Delaware are currently faced with significant areas of chronic flooding and are planning drainage improvement solutions for these issues. If future tidal levels are taken into account, these drainage improvement projects will be able to continue to manage water flows even as sea levels rise. Proactive adaptation in each of these areas has the potential for significant long-term cost savings for individuals and communities and may reduce loss of property and structures.

Existing Adaptive Capacity in Delaware

Significant adaptive capacity already exists within the state. Delaware has routinely replenished publically accessible beaches on the ocean and Delaware Bay coasts for over 40 years. It has a robust land acquisition program and a landuse regulation for coastal areas. It also requires counties and municipalities to plan for the future through comprehensive development plans. A brief summary of several of the key programs and legislation that have contributed to the state's existing adaptive capacity are outlined below.

#### Beach Preservation Act

Delaware's Beach Preservation Act (7 Del Code § 6801) gave DNREC the authority to enhance, preserve and protect public beaches and established a program for the prevention and repair of beach erosion. As a result, and with funding provided for projects through the Public Accommodations Tax, the beaches in Delaware from Fenwick Island to Pickering Beach have been routinely nourished with sand for over 40 years; a successful protection adaptation strategy that has minimized the effects of erosion and sea level rise.

The Beach Preservation Act also established a building line along the Delaware Bay and Atlantic coastline. Construction seaward of the building line is prohibited unless a permit is issued by the DNREC; permits can only be issued if a structure has been reduced in size to minimize encroachment over the line. This program has helped reduce the number of structures that could be vulnerable to erosion and sea level rise along the coast. The DNREC Division of Watershed Stewardship, Shoreline and Waterway Management Program is responsible for implementing the provisions of the Beach Preservation Act, and provides coordination and technical expertise for beach management issues statewide and throughout the region<sup>15</sup>.

#### Coastal Zone Act

Delaware's Coastal Zone Act (7 Del Code § 7001) prohibits new heavy industrial facilities and bulk transfer facilities within the coastal zone, an area of land generally east of Route 9, along the C&D

Canal and around Delaware's Inland Bays. Facilities in existence at the time of passage were grand-athered and permitted to continue operations. The act also requires that new manufacturing facilities, wastewater treatment plants not owned by a government entity, recycling plants and other similar facilities within this area receive permits prior to construction. Through its prohibition of new industrial development, the Coastal Zone Act has had a profound impact on coastal development, providing an opportunity for large scale conservation of low-lying land and minimizing the state's vulnerability to sea level rise impacts on population and infrastructure<sup>15</sup>.

#### Quality of Life Act

Delaware's Quality of Life Act (9 Del Code § 6951) requires that counties and municipalities in the state prepare and implement comprehensive development plans that identify future growth needs, annexation areas and major infrastructure needs. These plans must be consistent with state plans for spending and growth.

The Office of State Planning Coordination is responsible for implementing this act and reviewing comprehensive development plans for consistency with state policies. It also provides technical assistance on a range of planning issues for county and municipal governments and coordinates with state agencies when discrepancies arise. The preparation of comprehensive development plans and the existence of a central planning entity provide an important opportunity for cooperation and sharing of technology among state, county and municipal governments on cross-jurisdictional issues like sea level rise.

#### Multi-Hazard Mitigation Planning

The Delaware Emergency Management Agency (DEMA) is responsible for periodically preparing and implementing a statewide multi-hazard mitigation plan, which contains an assessment of vulnerability to a variety of natural and man-made risks, including flooding and storm surges. The plan also identifies actions that can be taken to reduce the risks. DEMA provides technical assistance

<sup>15</sup> More information about the Beach Preservation Act and building line can be found online: http://www.dnrec.delaware.gov/swc/Shoreline/Pages/ShorelineConstruction.aspx

<sup>16</sup> More information about the Coastal Zone Act can be found online: http://www.dnrec.delaware.gov/Admin/CZA/Pages/default.asp

to county and municipal governments that are developing their own mitigation plans or are applying for federal grants for hazard mitigation projects. In recognition of the expectation that flood and storm surge risks will be exacerbated in the future as a result of sea level rise, the 2013 update to the state's Multi-Hazard Mitigation plan includes consideration of sea level rise in its assessment and list of mitigation actions for flooding.

Many additional funding, regulatory and technical assistance programs exist to form the basis of the state's existing adaptive capacity<sup>17</sup>. These programs demonstrate how sea level rise planning and adaptation are already occurring within the state and how they can be incorporated into existing programs. Incorporation of sea level rise considerations into existing programs, rather than development of stand-alone programs, is a recurrent theme which is highlighted both in the guiding principles and the recommendations for adapting to sea level rise contained within this document.

#### Adaptation: From Individuals to States

A wide variety of individuals, communities, businesses and government agencies will choose to adapt through both implementation of on-the-ground adaptation measures and by building adaptive capacity. The various ways this can be achieved are outlined below. Many adaptation actions, whether they are capacity building or on-the-ground, will require cooperation and coordination with numerous entities. In addition, many adaptation actions are likely to be cross-jurisdictional, requiring the support and resources from communities, state entities and federal agencies.

#### Individuals and Business Owners

Individuals and business owners affected by sea level rise will make adaptation decisions primarily about the future of their own homes, land and businesses. Several of the recommendations proposed by the advisory committee are aimed at improving the ability of individuals and business owners to obtain information and technical assistance that will allow them to make the best decisions for their own particular circumstances. Individuals

and business-owners may choose to elevate or relocate structures further away from vulnerable areas. Alternatively, they may choose not to make any structural or location decisions based upon the anticipated consequences of sea level rise at their location. Individuals and business owners may also choose to help their community prepare for the impacts of sea level rise by participating in planning activities.

#### Communities, Municipalities and Counties

Community, municipal and county responses to sea level rise will likely involve planning, on-the-ground projects and capacity building.

Communities, municipalities and counties wishing to adapt to sea level rise may choose to begin planning for its effects through their comprehensive planning process or emergency management plans<sup>18</sup>. Communities and municipalities can also develop coastal resiliency plans. These plans focus specifically on coastal hazards in a particular location and outline goals and objectives, assess risks and identify actions to reduce the risks. Grant funding and technical assistance are available from several agencies for this purpose.

Local governments may identify necessary infrastructure projects and be responsible for designing, implementing, building public support and funding. These types of projects can range from improving drainage systems to restoring wetlands to maintaining dikes and tide gates.

Planning processes may also identify capacity building needs that can be implemented by a community or local municipality. Capacity building at a local level could include providing new residents and prospective homeowners with a place to obtain information about sea level rise, inundation impacts and flood insurance. They could also include building in-house technical capacity through hiring planning staff or training staff on software such as Geographic Information System (GIS).

<sup>17</sup> Appendix H contains a list of additional tools, programs and funding mechanisms

<sup>18</sup> See the City of Lewes case study in Chapter 4

State and Regional Agencies
Similar to county and municipal governments, state and regional agencies choosing to adapt can do so through strategic planning for management of their landholdings, choosing adaptation strategies for on-the-ground action and by improving their adaptive capacity. In addition, some state and regional agencies will likely provide technical and financial assistance to others for planning and selection of sea level rise adaptation strategies.

#### Timing of Adaptation

Whether for an individual, a community or a state agency, the time to begin sea level rise adaptation is now. The Sea Level Rise Advisory Committee has compiled a large volume of information to assist in mapping and understanding statewide vulnerability to sea level rise, but additional site-specific or resource-specific data and information may be needed before adaptation measures can be implemented in a particular location.

At a local or regional level, planning and responding to sea level rise may occur over many years, with several adaptation strategies being employed at the same time to address a number of different community goals for the future. Figure 3 below illustrates an example of short-term, medium-term and long-term adaptation measures that can be taken to meet an adaptation goal of reducing vulnerability to homes and shorelines. It is important to note that the four adaptation strategies described in the previous chapter may be undertaken simultaneously to meet this goal.

Adaptation, by its very definition, must be flexible over time because data improves, public perceptions change, and new technologies emerge.

Adaptation measures should be assessed and monitored over time, and long-term plans updated to incorporate new data and reflect changing conditions.

#### **Guiding Principles for Adaptation**

During the development of adaptation recommendations, the advisory committee had a number of discussions about how adaptation decisions should be made. For example, concerns were expressed about whether adaptation measures implemented in one location could have a negative impact on surrounding locations. Concerns

Short-Term • Increase set-back distances • Identify opportunities for voluntary conservation easements	ACCOMODATS  Short-Term • Improve evacuation plans • Flood-proof at-risk structures	Short-Term • Identify beaches with high erosion rates • Inspect dams and dikes	REFREAT Short-Term • Identify areas of high vulnerability
Medium-Term  Implement conservation easements  Monitor set back compliance	Medium-Term  • Require elevation of new homes to 18 inches above base flood elevation	Medium-Term  • Replenish beaches  • Conduct necessary repairs of dams and dikes	Medium-Term  Create a special fund for purchase of frequently flooded structures  Implement rolling easements
Long-Term  Continue monitoring set back compliance  Monitor conservation easements	Long-Term • Construct new drainage systems	Long-Term •Increase height of dikes	Long-Term  • Purchase frequently flooded areas from willing sellers and remove structures  • Monitor rolling easement compliance

Figure 3. Short-, medium- and long-term adaptation measures for addressing a goal of reducing vulnerability to homes and shorelines

were also expressed about how adaptation actions would be prioritized for state funding.

As a result of those discussions, the advisory committee has compiled the following "Guiding Principles for Adaptation." These principles should be taken into consideration during the planning and implementation of on-the-ground adaptation projects:

- Begin adaptation planning and implementation: adjust and make improvements as more information becomes available.
- Avoid unnecessarily prescriptive adaptation actions: empower decisions at the local level.
- Incorporate adaptation into existing programs and mechanisms, so as to not create a new bureaucracy. Engage broad public participation in adaptation decisions.
- · Use the best available science and technology for decision-making and adaptation actions.
- Coordinate and consider consequences of adaptation among jurisdictions and among resource
- Strike a balance between protection of homes, infrastructure and conservation of natural resources.
- Strive for equity in selection and funding of adaptation measures:
  - · Consider impacts to environmental justice communities.
  - ◆ Consider trade-offs between adaptation projects up-state and downstate.

- Encourage development of funding mechanisms for adaptation based on fairness, equity and justice for all citizens.
  - ♦ Public investment in sea level rise adaptation should be directed toward endeavors that benefit the most citizens as possible,
  - Public investment in sea level rise adaptation should be considered and weighed against the many needs of Delaware's citizens.
  - Fee based funding options, if developed, should be user-related (such as motor fuel taxes that pay for roadway maintenance).

## Chapter 4: Case Studies

As discussed in previous chapters, many sea level rise adaptation activities are already occurring in Delaware. This chapter highlights several notable initiatives that have been undertaken related to storm surge and sea level rise preparedness: innovative marsh management, public lands acquisition, dike restoration and community planning. Each of these initiatives is contributing to the state's adaptive capacity and can serve as an example of proactive adaptation to sea level rise.

# Accommodating Sea Level Rise by Elevating Marsh Surfaces

Tidal wetlands grow vertically by capturing sediment brought in by the tides, and by maintaining high plant production above ground and slow decomposition rates below ground. By accumulating dead plant matter and inorganic sediment, established marshes generally accrete at a rate sufficient to keep pace with sea level rise. However, the predicted accelerated rates of sea level rise will challenge this natural process.

When marshes do not accrete enough sediment to keep pace with rising sea levels, vegetation may die and portions of the marsh may become open water. This results in diminished flood storage capacity and reduced marsh habitat. One method to offset this sediment deficit is to reuse material dredged for navigation.

Sediments resulting from dredging of navigation channels are usually deposited in upland confined disposal sites, making those sediments unavailable in the natural system for marsh accretion. An alternative is to use the dredged material to increase the elevation of nearby tidal marshes. Applying a thin-layer of sediment over the marsh is a disposal option used successfully in other states and is currently being evaluated in Delaware as a sea level rise adaptation measure for tidal marshes.

A team of scientists from DNREC and the Center for the Inland Bays implemented a dredged material reuse pilot project in winter 2012 that is exhibiting initial signs of success. The project utilizes material from the maintenance dredging of Pepper Creek, near Dagsboro in Sussex County, to increase the elevation of an adjacent tidal marsh within the Piney Point Tract of the Assawoman Wildlife Area, This marsh was identified as having a comparatively lower elevation than other tidal wetlands in the Inland Bays and was therefore more vulnerable to rising sea levels.

Specialized equipment was constructed to transport the material from the dredge in the navigation channel to the shoreline. This included flexible piping and a pivoting nozzle mounted on a mini barge that could be moved along the marsh edge to direct the sprayed material. When the material is applied, it is a soupy mixture; about 85% water and 25% suspended sediment particles. The applied material will disperse across the marsh surface, leaving an even layer that will settle over

Dredging of Pepper Creek is planned to continue in winter 2013; up to six inches of dredged material will be placed on the large emergent wetland.

Scientists will continue to monitor for various indicators such as surface elevation, plant cover and below ground root mass for comparison to pre-project conditions. The results will be used to guide future marsh restoration projects.

# Incorporating Sea Level Rise into Public Lands Acquisition

It is anticipated that 37% to 44% of the state's permanently protected land could be inundated by sea level rise under the three planning scenarios (DNREC Delaware Coastal Programs, 2012). Delaware's Open Space Program coordinates state acquisition of parks, fish and wildlife areas, forests, nature preserves and cultural sites.

In order to carry out the purposes of the Open Space Program, an Open Space Council provides recommendations to the Secretary of DNREC on all matters relating to the administration, implementation and financing of the protection of land. Because the Council typically works in a constrained environment of limited funding, a ranking process was developed to provide a strategic way of preserving open space by evaluating a property based on its own features compared to those of other similarly ranked properties in order to maximize resource benefits and to leverage all relevant funding sources.

Point values are assigned for parcels under consideration based upon specific attributes within the following categories: ecological value (e.g., habitats of conservation concern or presence of rare plants or animals), land use (e.g., proximity to existing preserved lands, development pressure, and access issues), cultural/historical resources, water features (e.g., presence of riparian buffers or natural streams), and recreational uses.

The ability of a parcel to provide a means for sea level rise adaptation is a criterion under the land use category. Using the inundation scenario maps, properties with a landscape position that may allow landward migration of wetlands, for example an upland area adjacent to wetlands that may become open water as sea levels rise, would score higher in this particular sub-category than properties that are currently or predicted to be inundated as waters rise.

Recently, a potential acquisition known as the Morris property scored high in numerous categories, including ecological importance and land use, and also met the criterion for wetland migration potential. The Morris property Is a 740-acre parcel to be purchased in 2013 with a combination of conservation grants and Open Space Program funding. The property, located northwest of the town of Bowers Beach in Kent



Sediment diedged to maintain navigable waterways can be used to elevate marsh surfaces. Here, material (rom Pepper Creek near Dagsboon in Sussex County is being spayed on a marsh within the Assawoman Wildlife Area as part of a dredged material rows poll project.



The Morris Property will purchased by the State of Delaware with conservation grants and Open Space Program that Other It contains a mix of habitat types including uplands adjacent to Idad marsh, which may allow for manihes to naturally move inland in response to see level rise.

County, contains a mix of habitat types including uplands adjacent to tidal marsh, which would allow marshes to naturally move inland in response to sea level rise. Preserving the property will also protect habitats of conservation concern, expand the boundary of the Ted Harvey Wildlife Area, and preserve additional lands within the Delaware National Estuarine Research Reserve core area. The Delaware Ornithological Society and Delaware Wild Lands, among other private and public funding sources will partner with DNREC for the purchase.

#### Holding Back the River with the New Castle Dike Restoration Project

Historic dikes, portions of which date back to the mid to late 1600's, form an earthen barrier between the city of New Castle and the Delaware River. Initially the dikes were constructed to hold back the river, thereby increasing lands suitable for agriculture. A secondary benefit was protection from flooding from coastal storms. Currently, four dikes line the Delaware River within New Castle: Buttonwood Dike, Broad Marsh Dike, Gambacorta Dike and Army Creek Dike. Another dike, located just to the south, also plays an important role in flood protection for the area.

Maintenance is necessary to sustain the integrity of these structures, and is typically very expensive. Over time, the responsibility of maintaining these structures, including removal of vegetation, repair of scoured and eroded banks, and removal of animal burrows, passed from one group to another. These groups were primarily stakeholders with an interest in the continued existence of the dikes, and they built, repaired and rebuilt them as necessary.

Dikes are continually impacted by wind, waves and tide; natural forces that can gradually erode and weaken the face of these structures or cause significant damage during coastal storm events. Seepage, or water permeating through the structure via cracks or animal burrows, can also compromise the integrity of the structure. Erosion, overtopping, and seepage are all factors that may lead to a dike's collapse and these negative effects are exacerbated by sea level rise (DNREC Delaware Coastal Programs, 2012).



Dikes protecting the City of New Castle are in need of tocon struction in order to increase the creat height and resiliency to coastal storns and sea level tise, and to be aligible for tecked intending for tuture repairs. A walking path on Army Creek dike, shown here, has been undermined by erosion and is in need of repair.

Recognizing the need to evaluate the integrity of the dikes and decrease the city of New Castle's vulnerability, DNREC's Delaware Coastal Programs funded a study to assess the condition of the four dikes within the city. Not unexpectedly, the results indicated that a combination of decades of neglect, a decrease in the protective wetlands buffering wave energy from the river, and a recent string of coastal storms resulted in an unacceptable state of disrepair. Multiple agencies and stakeholders were needed to coordinate a response to address the deficiencies.

The New Castle Dike Maintenance Advisory Committee was created with representatives from the city of New Castle, DNREC, the Delaware Department of Transportation, the Delaware Emergency Management Agency, New Castle Commons and residents of the city. The committee set out to devise a maintenance plan and evaluate repair options. One option was a full reconstruction of each dike, an approach that was too costly for the city if done all at once. Undertaken as a step-bystep approach, this option would cost more over time but could be done as funds became available.

A series of coastal storms heavily battered all of the dikes and it became apparent that their reconstruction needed to occur soon in order to protect the health, safety and property of the residents and businesses in the region. The Delaware Legislature allocated initial funding, which covered the cost for design, archeological studies, permitting, and a portion of construction.

Total construction costs are estimated to reach nearly \$10 million, making this a major multi-year undertaking. The project timeline was hastened after Hurricane Sandy struck in October 2012 and resulted in the near failure of several dikes. Current plans are to have all five dikes repaired and raised to an elevation that will provide greater protection, and would make the dikes eligible for inclusion in the US Army Corps of Engineers' Rehabilitation and Inspection Program (RIP) by the end of 2013, Inclusion in the RIP allows for 80% of the costs for future damages to the structures to be covered by the USACE.

Operations and maintenance plans, which will identify inspection requirements and outline responsible parties for management activities, are being developed for each of the five dikes.

#### City of Lewes Hazard Mitigation and Climate Adaptation Pilot Project

The Sea Level Rise Advisory Committee report, Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware (2012) identified the need for detailed vulnerability assessments to be performed at the local level to determine specific resources at risk within communities. One municipality has already completed this analysis and adopted a plan to better prepare for coastal hazards that incorporates future flood risk and potential sea level rise impacts.

The City of Lewes is a quiet resort town on the mouth of the Delaware Bay. It is known for its historic district and small town atmosphere and has many natural features such as tidal creeks and wetlands, sandy beaches, and agricultural lands. The Lewes and Rehoboth Canal, a manmade waterway, bisects the town, which is highly

vulnerable to many natural hazards, including coastal storms, flooding, and high winds.

Coastal storms have caused severe damage in the past. The March 1962 Ash Wednesday storm is the most notorious. The surge associated with this storm resulted in a record tide level of 1.4 meters above mean higher-high water (NOAA, 2013). More recent storms in 2008, 2009 and Hurricane Sandy in 2012, brought widespread flooding of low-lying areas and evacuation routes. Their current vulnerability, coupled with projected accelerated sea level rise, spurred the city to be proactive in addressing their risks. The City of Lewes partnered with the University of Delaware's Sea Grant Program and ICLEI Local Governments for Sustainability to develop the City of Lewes Hazard Mitigation and Climate Adaptation Plan, which was completed in June 2011 and adopted by Mayor and Council in August 2011<sup>19</sup>.

The plan was a culmination of the efforts of local officials and residents who participated in a series of workshops to identify existing and future vulnerabilities and ways to reduce potential impacts. Several key vulnerabilities were identified: (1) flood impacts to homes, property, and land use, (2) flood impacts to city infrastructure, and (3) impacts to water resources due to precipitation pattern changes, flooding, and salt water intrusion. The City adopted a plan that includes six specific actions and implementation guidance to integrate its hazard mitigation and climate adaptation efforts. Actions identified to address key vulnerabilities fit within the following general categories:

- Knowledge building, including further study of evacuation route vulnerability and updating education and outreach programs
- Incentives, specifically the improvement of the city's participation in the Community Rating System to reduce citizens' flood insurance premiums
- Planning and regulatory recommendations

<sup>19</sup> Full text of the City of Lewes plan and more information on the planning process can be found online: http://www.deseagrant.org/lewes\_pilot\_project

The planning document also includes guidance to help the City of Lewes begin to implement the identified actions to achieve greater resiliency to coastal hazards and climate change. Planning exercises such as this one, and the subsequent adoption of the plan by the Town Council, positions local municipalities for grant funding for implementation projects and helps to maintain a consistent focus as changes occur in council membership and other town leadership positions.



The City of Lewes is a quiet resort lown at the mouth of the Delaware Bay that is vulnerable to many natural hazards including costad storms, flooding and high winds. Recognition of these risks prompted the development and adoption of the City of Lewes Hazard Mittgation and Climate Adaptation Plan to prepare for future weather events.

# Chapter 5: Development of Recommendations for Adapting to Sea Level Rise in Delaware

This chapter outlines the rationale and process used for the development of the Recommendations for Adapting to Sea Level Rise in Delaware. It also details the public and stakeholder processes used to generate information and ideas and discusses the decision-making process of the Sea Level Rise Advisory

#### Focusing Recommendations on Priority Resources

The Sea Level Rise Advisory Committee was charged by DNREC Secretary Collin O'Mara with assessing the state's vulnerability to sea level rise and developing recommendations for the state to prepare and respond to the challenges it poses. The state's vulnerability to sea level rise was comprehensively assessed in the 2012 document Preparing for Tomorrow's High Tide, Sea Level Rise Vulnerability Assessment for the State of Delaware<sup>20</sup>, highlights of which are outlined in Chapter 1 of this document. The assessment identified and characterized the vulnerability of 79 resources to sea level rise impacts. It also ranked each vulnerable resource as having a high, moderate or low concern statewide. Through this process, 16 resources were identified as being of high concern, and 6 of moderate concern.

Developing recommendations that would encompass all 79 vulnerable resources was not possible with available time and resources, so the advisory committee focused its work on developing recommendations for resources of high and moderate concern statewide. Focusing recommendations only on these 22 resources allowed the advisory committee to conduct a more in-depth investigation of barriers to adaptation

and potential improvements to adaptive capacity for these resources. While several of the recommendations approved by the committee have implications for all vulnerable resources, the majority have a more limited scope.

#### Resources of High Concern

Beaches and Dunes Coastal Impoundments Dams, Dikes and Levees Evacuation Routes Freshwater Tidal Wetlands Future Development Areas Habitats of Conservation Concern Heavy Industrial Areas Port of Wilmington Protected Lands Statewide Roads and Bridges Railroad Lines Tidal Wetlands Tourism and Coastal Recreation
U.S. Fish and Wildlife Service Refuges

20 Available online: http://de.gov/slrva

#### Building Adaptive Capacity versus Local Adaptation Measures

From the beginning of this initiative, the Sea Level Rise Advisory Committee recognized that its recommendations could not be place-based. Decisions about the adaptation strategies to be utilized in a particular area will need to be informed by local conditions, site-specific engineering, community desires and the availability of funding, among other considerations. For a statewide planning process to weigh in on local adaptation strategies without the benefit of site-specific information would be inappropriate. However, understanding the range of actions that may be taken in the future in specific places (as outlined in Chapter 2) is important for ensuring that adequate coordination, regulations, policies, management practices and funding are available. For this reason, the process of developing recommendations for adaptation focused on actions that could be taken to increase Delaware's adaptive capacity.

# The Process for Developing Options for Preparing Delaware for Sea Level Rise

The first step in development of recommendations to increase adaptive capacity was to create a comprehensive list of actions that could be considered. Development of this list of actions was initiated at stakeholder focus groups and then refined by the Sea Level Rise Advisory Committee.

#### Focus Groups

In October 2012, six focus group sessions were held for the purpose of increasing stakeholder involvement and creating a list of actions that could be taken to improve Delaware's capacity to adapt to sea level rise. The focus groups centered on high and moderate concern resources, categorized as follows:

Coastal Defenses, including beaches and dunes, dams, dikes and levees, and tourism

**Industrial Land Use**, including industrially zoned land, landfills and salvage yards, and Port of Wilmington

Land Preservation and Habitat, including coastal impoundments, protected lands statewide, U.S. Fish and Wildlife Service lands, nature preserves, tidal and non-tidal wetlands, tourism, and habitats of conservation concern

Land Use, including agricultural conservation areas, future development areas, and residential

**Transportation**, including evacuation routes, railroads, roads, and bridges

Water and Wastewater, including septic systems, wastewater treatment and transmission facilities, and wells

For each focus group, key stakeholders, including individuals, agencies and businesses not represented on the advisory committee but who could be affected by sea level rise were invited to participate. See Appendix D for a full list of focus group participants. The focus groups were attended by 77 persons.

Participants in each focus group reviewed the vulnerabilities of their specific resource categories and discussed the suite of potential adaptation strategies that could be taken in the future. Participants were then asked if there were adequate tools in place for individuals, businesses and governments to plan for, choose and implement adaptation strategies. Where tools were not adequate, participants were asked to list ways to improve and build the capacity to adapt. They were specifically asked to list any improvements that could be made to the following: funding mechanisms and financial incentives, coordination and planning tools, regulatory and policy tools, data and information and, outreach and education.

The focus groups identified over 100 ideas for improving the state's capacity to adapt to sea level rise.

#### Refining Focus Group Ideas

Over a three-month period, the advisory committee reviewed ideas and debated their benefits and consequences. A summary of the rationale

and impact of each idea was also drafted and reviewed. After significant review and discussion, the advisory committee retained 61 ideas. As all 61 did not have the full support of the advisory committee, public input was solicited prior to their incorporation into a final list of recommendations for adaptation. The ideas were compiled into a document entitled Options for Preparing Delaware for Sea Level Rise. This document was distributed to the public for comments at public engagement sessions and electronically.

#### Public Engagement Sessions

To share information about potential adaptation strategies and to obtain public input on the 61 options, the Sea Level Rise Advisory Committee hosted three Adaptation Engagement Sessions in February, 2013.

In total, 236 people attended the three public engagement sessions, held in the cities of New Castle, Dover and Lewes. For those not able to attend, all presentations and displays were posted online. Participants were able to provide comments at the meeting, online, by email or by US mail. A total of 57 written comments were received. Comments were reviewed and considered by the committee as they made their final list of recommendations. A summary of comments received is available in Appendix E.

#### **Turning Options into Recommendations**

After consideration of the public comments and additional debate among Sea Level Rise Advisory Committee members, the 61 options were revised. The revised options were then voted on by Committee members. In all, 55 options had the necessary support of two-thirds of committee members to be included in this document as final recommendations of the Sea Level Rise Advisory Committee<sup>21</sup>,

During its discussions and decision-making process, the Sea Level Rise Advisory Committee strove for consensus. Building consensus for adaptation options required significant compromise on several options and resulted in the omission

of others. However, the final recommendations of this advisory committee have strong support amongst almost all advisory committee members. See Appendix B for dissenting opinions of advisory committee members.



Participants at the Lewes Adaptation Pub Session gather around a map of the state sh could be inundated by sea level rise in 2100

<sup>&</sup>lt;sup>21</sup> A record of the votes cast by each advisory committee member organization can be found online: http://www.dnrec.delaware.gov/coastal/ Documents/SLR%20Advisory%20Committee/Meeting19May2013/ResultsofFinalVoteswithMotions.pdf

# Chapter 6: Recommendations for Adapting to Sea Level Rise in Delaware

Delaware's Sea Level Rise Advisory Committee was charged with developing recommendations for adapting the state to the likely impacts of sea level rise. Because sea level rise adaptation will occur at many different geographic levels—from an individual home to a regional transportation network—the Sea Level Rise Advisory Committee focused its efforts on researching and developing recommendations that will build the state's capacity to adapt, rather than pinpointing adaptation measures that should be used in specific locations. As a result, the Sea Level Rise Advisory Committee approved 55 recommendations for adapting to sea level rise that meet seven capacity building objectives. This chapter provides a complete list and description of each recommendation of the advisory committee.

#### Objectives for Sea Level Rise Adaptation

The goal of the Sea Level Rise Advisory Committee, in part, was to "develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, and business practices and to make informed decisions." As described in previous sections, the Sea Level Rise Advisory Committee spent considerable time gathering input from their organizations, other stakeholder groups, and the public to determine whether barriers and opportunities for adaptation exist for the vulnerable resources identified as of high or moderate concern. Seven objectives for building capacity to adapt to sea level rise emerged from these discussions:

- Improve Communication and Coordination among State, Federal, Local and Regional Partners to Streamline Sea Level Rise Adaptation Efforts.
- Provide Increased Regulatory Flexibility for Adaptation and Improve Consistency among Regulatory Agency Decisions.

- Provide Consistent and Predictable Policies for Future Growth, Investment, and Natural Resource Management.
- Increase Public Awareness of Sea Level Rise through Education, Outreach and Marketing.
- Improve the Availability and Robustness of Sea Level Rise Data Sets.
- Provide Technical Assistance to Partners for Assessing Vulnerability and Choosing Adaptation Strategies.
- Expand Funding Opportunities for Adaptation Planning and Implementation Projects.

The final recommendations of the Sea Level Rise Advisory Committee are grouped below according to the objective it will most help achieve, although there may be recommendations that meet more than one objective.

Recommendations for Adapting to Sea Level Rise in Delaware

The Recommendations for Adapting to Sea Level Rise in Delaware have been presented to Collin O'Mara, Secretary of the Department of Natural Resources and Environmental Control as the final product of Delaware's Sea Level Rise Advisory Committee. These recommendations are intended to provide a starting point for state, local and individual efforts to improve Delaware's ability to adapt to sea level rise; they do not represent a regulatory or statutory action.

Although these recommendations were developed at the request of the DNREC Secretary, they do not address only issues under the jurisdiction of DNREC. Many will require the support and cooperation of other agencies and groups to be implemented.

The recommendations below have not been prioritized by the Sea Level Rise Advisory Committee but are organized by objective, with recommendations numbered in a way that groups similar recommendations together for ease of reading. Prioritizing recommendations for implementation will occur at a later date, as outlined in the Chapter 7. Appendix A provides a table identifying the vulnerable resource each recommendation addresses.

Objective 1: Improve Communication and Coordination among State, Federal, Local and Regional Partners to Streamline Sea Level Rise Adaptation Efforts

Sea Level Rise Advisory Committee members, public engagement session attendees and stakeholder groups consulted during the development of these recommendations often expressed the need for improved coordination across jurisdictional and resource boundaries. The seven recommendations below are aimed at improving the ability of stakeholders at different organizational levels to coordinate and share information related to sea level rise and inundation.

## Recommendation 1.1: Improve coordination of permit decisions for adaptation projects among federal, state and local officials.

Permitting processes that involve several different agencies, particularly those for transportation, sewer infrastructure, shoreline protection, and commercial or residential development, can be delayed when agencies lack a common set of goals or have conflicting regulatory requirements. As sea level rise adaptation becomes incorporated into project proposals, conflicting regulations may delay permitting processes. Early coordination of projects between state, federal and local officials could help minimize regulatory conflicts and delays, as would incorporation of sea level rise consideration into regulatory decisions. These actions may lead to more rapid issuance of permits for adaptation projects, more predictability and empowerment for local governments when planning and designing their own adaptation projects.

## Recommendation 1.2: Create new partnerships to increase resources for research and development of adaptation options.

New and innovative solutions may exist for adaptation to sea level rise, including new shoreline stabilization methods, wave attenuation structures, oyster reefs, and offshore structures. Pilot projects to determine the efficacy of untested techniques may yield positive results. Forming new partnerships or strengthening existing partnerships with neighboring states, federal agencies, the consulting community, universities, and non-profits will greatly expand the knowledge and funding available for research and development. Collaboration can also expand regional sediment management research and opportunities for beneficial reuse of dredged spoil

#### Recommendation 1.3: Increase opportunities for technology transfers and regional coordination for transportation issues affected by sea level rise.

Delaware, Maryland, Pennsylvania and New Jersey have an integrated road, bridge and railway system which will require coordination and cooperation among the states and the U.S. Department of Transportation to adequately address sea level rise. Using existing professional venues, such as

regional Metropolitan Planning Organizations and the American Association of State Highway Transportation Officials, DelDOT should integrate this new dimension into its planning, design, and operation policy discussions and standards development.

### Recommendation 1.4: Incorporate sea level rise into public and private sector regional planning efforts.

Much of Delaware's infrastructure is part of regional networks, including electrical generation, roads, rail, and landfills. Delaware's wetlands, habitats of conservation concern, beaches and nature preserves are also part of a regional system of wildlife and fish habitats. Incorporation of a common set of sea level rise information into regional planning processes for these resources will help ensure that informed decisions about adaptation are made and that the entire regional system is sustainable. Regional planning processes that should be targeted include: Wilmington Area Planning Council and Dover/Kent Metropolitan Planning Council long range plans for transportation, Amtrak long range plans, business group and industry contingency plans, and regional habitat plans

## Recommendation 1.5: Provide sea level rise information to the Delaware Agricultural Land Preservation Program for consideration.

The Agricultural Land Preservation Program protects land for agricultural purposes through voluntary measures. Included armong these are the purchases of preservation easements that permanently protect farmland from development while allowing agricultural uses to continue. High quality soils, significant agricultural infrastructure, historical and environmental significance are all factors that have been considered in program eligibility.

# Recommendation 1.6: Provide technical assistance to Delaware's Open Space Council for incorporating sea level rise into its criteria for acquisition of natural areas.

Delaware's Open Space Council works to secure the permanent protection of open spaces in Delaware including parklands, forests, fish and wildlife areas, nature preserves and cultural sites. The Open Space Council has developed criteria that it uses to prioritize and assess potential land purchases. Sea level rise has been included in these criteria, but additional assistance may be necessary to further refine and modify the criteria.

# Recommendation 1.7: Conduct a comprehensive inventory of key funding, coordination, regulations and policies and analyze them for barriers and opportunities for sea level rise adaptation.

Many recommendations of the Sea Level Rise Advisory Committee propose changes that would remove obstacles for adaptation and increase coordination among agencies. However, many other barriers and opportunities may exist that could not be considered within the time frame of the advisory committee's work. A comprehensive study of key funding, coordination, regulation and policies could help shed light on opportunities for coordination and removal of barriers that had not previously been considered. Private sector plans could also be considered and incorporated.

#### Objective 2: Provide Increased Regulatory Flexibility for Adaptation and Improve Consistency among Regulatory Agency Decisions

Sea Level Rise Advisory Committee members, public engagement session attendees and stakeholder groups consulted during the development of these recommendations were concerned that regulatory agencies in the state could respond to sea level rise by implementing or retaining contradictory regulatory and policy changes. There was also concern that there could be negative consequences if regulations do not consider the potential impact of sea level rise; both because sea level rise can change the ability of a project to meet a technical standard and because adapting to sea level rise may require regulatory flexibility that does not yet exist. The following six recommendations are aimed at ensuring that sea level rise is considered during future regulatory updates for certain environmental regulatory programs and ensuring that state agencies work together in considering the impact of sea level rise on the implementation of their programs.

### Recommendation 2.1: Provide regulatory incentives that encourage sea level rise adaptation and that allow for innovative projects.

Sea level rise is an emerging issue that many state and local regulations do not yet consider. A variety of adaptation measures from raising buildings to protecting shorelines may not be permissible or may take longer to permit than measures which do not include sea level rise considerations, setting up a perverse incentive that could result in no adaptation or maladaptation. Local and state regulations and building codes should be assessed for opportunities to provide incentives for adaptation, particularly for demonstration projects. As an example, the Delaware Department of Natural Resources and Environmental Control recently issued a "Statewide Activity Approval" for shoreline stabilization projects that incorporate natural and planted marshes. Under this approval, average permitting times will be reduced to one to two weeks.

### Recommendation 2.2: Encourage the governor to sign an executive order that would direct state agencies to plan for sea level rise.

The vulnerability assessment demonstrates that sea level rise has consequences throughout the state and to a wide variety of resources. Adapting to sea level rise at the state level will require state agencies to work together using a consistent set of data and predictions. An executive order could direct each state agency to conduct an agency specific vulnerability assessment using a common set of future scenarios. It could also direct each agency to consider future sea levels in the design of state projects and infrastructure, identify adaptation plans for state owned assets, and identify regulatory and policy opportunities and barriers.

# Recommendation 2.3: Conduct a comprehensive update to the state's regulatory tidal wetlands maps and provide a way to periodically update the maps to reflect changes occurring from sea level rise.

changes occurring from sea level rise. Activities in tidal wetlands are regulated by the state through its Wetlands Act (Del Code 7, Chapter 66). Tidal wetlands were inventoried and drawn on maps; any tidal wetland depicted on this map is regulated by the state. However, the aerial photographs for these maps were flown in 1988 and have not been comprehensively updated since

then. Sea level rise, erosion and coastal storms cause wetlands to migrate; the existing maps may no longer be accurate. The vulnerability assessment concluded that 99% of the state's existing tidal wetlands could be inundated by sea level rise – comprehensively updating the regulatory wetland maps on a routine basis will help protect tidal wetland areas that migrate land ward.

#### Recommendation 2.4: Consider sea level rise implications in future regulatory updates for septic systems and wells.

Sea level rise and its associated impacts, such as increased flooding, rising water table, and salt water intrusion, can reduce or eliminate the functionality of on-site wastewater treatment systems and groundwater wells. Permit criteria for the siting, design, and construction of wastewater disposal systems and wells are specified in state regulations. Incorporating sea level rise considerations into future updates of these regulations to implement protective design and siting requirements could reduce vulnerability of septic systems and wells. Additional studies of sea level rise implications for Delaware's groundwater would be necessary before criteria could be developed. The costs of any additional requirements should be carefully considered and weighed against the lifespan of each system.

# Recommendation 2.5: Facilitate the connection of individual septic systems to community wastewater treatment systems with excess capacity when human safety and welfare are at risk.

The vulnerability assessment identified over 3,000 septic systems at risk of inundation in Delaware many of these could begin to fail prior to inundation due to rising water tables. Although it is possible to provide central sewer service to residents with failing septic systems, in some cases it is not economically feasible to do so. In these cases, it may be feasible to connect failing septic systems to nearby community wastewater treatment systems that have excess treatment capacity. This would allow systems failing due to sea level rise to connect to a treatment facility as an interim measure that may expand the lifespan of a residence in a vulnerable area. An agreement would have to be made between the individual landowner and the operator of the community system. It is unknown

at this point if the costs would be the sole responsibility of the landowner or if existing grant and loan programs could be utilized to defray costs. There is concern that allowing connection to community systems could foster residential growth in vulnerable areas.

## Recommendation 2.6: Consider sea level rise implications in future updates to the state Coastal Zone Act regulations.

Delaware's Coastal Zone Act prohibits new heavy industrial uses in the coastal zone and requires permits and environmental offset projects for modifications to existing heavy industrial facilities. Existing heavy industry in the coastal zone is very important to Delaware's economy; these facilities should be allowed the flexibility to adapt to sea level rise. Sea level rise considerations, including the potential future need for shoreline improvements, drainage improvements and facility upgrades, should be included in any future regulatory updates.

# Objective 3: Provide Consistent and Predictable Policies for Future Growth, Investment, and Natural Resource Management.

During conversations and meetings with stakeholders, a desire for predictable land use, management and investment policies emerged. Clearly articulating strategies for adapting to sea level rise early will help these stakeholders make informed decisions about where they locate and invest. The following 14 recommendations are aimed at providing consistency for growth and investment by identifying planning documents and tools that should incorporate sea level rise as a consideration, identifying new plans that should be developed, and calling for development of decision-making tools.

## Recommendation 3.1: Incorporate sea level rise considerations into the Strategies for State Policies and Spending.

Land-use decisions in Delaware are made at the local level, but the bulk of infrastructure and service that support these decisions are funded by the state. The Strategies for State Policies and Spending set forth clear advisory policies (including maps) about where the state will allocate financial resources for conservation,

infrastructure improvements, and social services and are updated every five years. Incorporation of sea level rise into the suite of issues considered when the strategies are updated would provide an opportunity for coordination between agencies and local governments regarding sea level rise and may help further ensure wise use of state funding.

### Recommendation 3.2: Consider incorporation of sea level rise considerations into municipal

and county comprehensive development plans. State law requires that every municipality in Delaware develop, and periodically update, a comprehensive development plan. These plans contain a municipal development strategy that includes expansion of boundaries, future plans for residential and commercial growth, and future infrastructure investments, among others. They also contain environmental and demographic information. Consideration of sea level rise impacts and potential adaptation actions would ensure that all municipalities in the state are proactively taking into account potential sea level rise impacts in their future plans for growth and development and may allow for increased communication about sea level rise between municipal, county and state governments.

#### Recommendation 3.3: Consider use of a Transfer of Development Rights tool to direct future growth away from vulnerable areas.

A Transfer of Development Rights (TDR) tool helps to direct future growth away from vulnerable areas by allowing for increased densities in areas more appropriate for development. This could help to ensure future growth needs are met by utilizing land outside of potentially vulnerable areas. TDRs have been used by county governments to direct residential and commercial growth away from agricultural areas, but their use is not yet widespread.

## Recommendation 3.4: Incorporate sea level rise into Delaware's Long Range Transportation Plan.

Delaware's Long Range Transportation Plan serves as a strategic planning tool for the state to chart the course of transportation for the next 20 years. Including sea level rise in the evaluation of transportation needs, and as a specific statement in the plan, will provide the necessary policy support for DelDOT to incorporate sea level rise into

project planning, establish a framework for directing investments, and identify financial resources to sustain the plan's vision.

### Recommendation 3.5: Incorporate sea level rise into the Transportation Operations Management Plan

Management Plan.
Future updates to DelDOT's Transportation Operations Management Plan for each county should consider sea level rise impacts on the safe and efficient operation of the state's roadways and on evacuation route planning.

### Recommendation 3.6: Encourage inclusion of sea level rise in Transportation Project Design Manuals

To ensure consistency of highway infrastructure across the country, national standards are cooperatively developed by state Department of Transportations and the Federal Highway Administration under the banner of the American Association of State Highway and Transportation Officials. These adopted standards cover all aspects of design and road geometry, as well as signals, signs and markings. These standards need to be updated to reflect the predicted effects of sea level rise on such long-lived assets such as roadways and bridges, accounting for differences in sea level rise scenarios in different areas of the nation.

### Recommendation 3.7: Develop a dike safety program.

There are numerous dikes throughout the state that act to protect infrastructure, natural resources and private property from flooding during storms and extreme high tides. However, there is no single entity in charge of inspecting, maintaining and improving these dikes. The dikes are also owned by a variety of different entities, further complicating their management and operation. The creation of a Dike Safety Program would ensure a single point of contact for dike repairs and management. It could also be responsible for conducting feasibility studies for improving or abandoning dikes and obtaining funding for repairs and upgrades. A similar program has recently been implemented for dams within the state. Creation of such a program may require new legislation.

# Recommendation 3.8: Develop a framework for decision-making regarding land protection and restoration strategies based on habitat vulnerability, migration potential and relative importance in the regional landscape, historical significance or other key factors.

In order to prioritize land acquisition and protection strategies in light of sea level rise impacts, a decision tree, process model, cost/benefit analysis, or similar tools are needed. The U.S. Geological Survey is developing a computer model to prioritize habitat types for the northeast region. Upon completion, this model may assist in determining priority needs that consider a broader, regional context. Consideration should also be given to the ecological services provided by these lands and economic values placed on them. Land acquisition should be aggressively targeted for the highly ranked habitat types.

#### Recommendation 3.9: Develop a comprehensive wetlands restoration, protection and retreat strategy in response to sea level rise.

A comprehensive wetlands restoration strategy for the state is necessary given the anticipated impacts from sea level rise. The strategy should include: identification of uplands for preservation and acquisition to provide areas for marsh migration; prevention of the construction of structures that would act as barriers to migration; identification of wetland restoration techniques to allow wetlands to keep pace with sea level rise; cataloging of pertinent research needs; identification of policy and regulatory changes, and; development of an outreach strategy. Specific ideas that could also be incorporated include evaluating Phragmites control techniques, beneficial re-use of sediment, and rolling easements.

### Recommendation 3.10: Continue efforts to re-evaluate management strategies for existing coastal impoundments.

The DNREC Division of Fish and Wildlife and the U.S. Fish and Wildlife Service own and operate coastal impoundments in the state that provide bird habitat, fish nursery grounds, and flood abatement. In recognition that current management practices for impoundments may be unsustain-

able in light of sea level rise, the Division of Fish and Wildlife has begun research and planning to improve impoundment management and develop adaptation strategies. Future management strategies could consider incorporating beneficial re-use of dredge disposal sediments to build up elevation and possibly adjusting locations of impoundments after considering the landscape and resource needs. Lessons learned from pilot projects and new management techniques should be shared with the U.S. Fish and Wildlife Service and others throughout the region that manage impoundment structures. Outreach to surrounding communities about any changes to impoundment management should also be considered.

## Recommendation 3.11: Evaluate the benefits and risks of permitting privately owned coastal impoundments.

The vulnerability assessment found that virtually all of the state's coastal impoundments are vulnerable to sea level rise. These areas provide important breeding, migration and wintering habitat for birds and serve as nursery grounds for fish. Construction of coastal impoundments in state regulated tidal wetlands is rarely approved due to a variety of natural resource concerns, habitat management issues and impacts to surrounding landowners. However, in light of potential losses of existing large impoundments, providing similar alternatives at a smaller scale can provide beneficial habitat if impoundments are properly managed. An endow-ment could be required for any new impoundment to ensure future maintenance. Conservation easements, which would provide permanent protection to the land and direct management practices, should also be required. Impacts to local hydrology. mosquito control, flooding and drainage issues and potential liabilities will need to be evaluated prior to permitting new impoundments on private

### Recommendation 3.12: Designate shoreline zones for adaptation action.

Shoreline protection and restoration projects require federal, state and sometimes local permits. Hardening of shorelines (e.g., with bulkheads or inprap) is generally discouraged by state policies, but may be the most appropriate adaptation response in urban or industrial areas. Conversely,

soft or "living" shorelines may be the most appropriate in rural or environmentally sensitive areas. Criteria for shoreline adaptation would have to be based on peer-reviewed literature and done in collaboration with stakeholders. Planning for and designating areas statewide where shoreline hardening would be allowed, where hardening would be discouraged, and where living shorelines will be encouraged will provide certainty for permit applicants and may streamline the permitting process. These designations should also be incorporated into appropriate federal, state and local permitting processes.

## Recommendation 3.13: Conduct a legal review for disinvestment of publicly owned infrastructure and privately owned buildings.

Retreat is an important strategic option for dealing with sea level rise. Many private and public buildings and other infrastructure, such as roads, may become impractical to maintain as the environment changes and may be abandoned. There are many public health and safety implications that must be addressed, such as removal of contaminants, as well as legal implications, such as loss of access to a property or loss of property value due to removal of an inter-related public or private asset. In addition, there are also equal protection and environmental justice implications for low income and/or minority communities that could be affected by disinvestment. A review of the legal framework, especially real estate and environmental law, will be needed in order to begin to understand the legal feasibility as well as true costs and consequences of a retreat strategy.

### Recommendation 3.14: Develop a statewide retreat plan and update it periodically.

There are certain locations within the state where "retreat" may be the best adaptation strategy, including some natural areas, agricultural areas and developed areas where protection may not be feasible due to expense or engineering constraints. There is a desire from businesses, clitizens and state agencies to have predictability in adaptation responses so that they can make long-term plans. A statewide plan outlining areas where retreat may be the most appropriate adaptation option would allow state agencies to put lifespan limits on infrastructure in vulnerable areas, allow targeted

land acquisition for inland migration of wetlands and shorellines, and provide predictability for citizens. Significant new data about adaptation costs, shoreline responses to sea level rise and demographic information would be required before a retreat strategy could be crafted. Any retreat plan would also require extensive dialogue with elected officials, business and commercial property owners and citizens.

#### Objective 4: Increase Public Awareness of Sea Level Rise through Education, Outreach and Marketing

Availability of information to improve decision-making in the face of changing conditions caused by sea level rise was immediately recognized by the Sea Level Rise Advisory Committee as an important component of adaptation planning, the importance of which was reinforced during stakeholder and public meetings. The following four recommendations, coupled with several listed under Objective 5, seek to ensure that those wishing to incorporate future sea levels into their planning and decision-making have access to the tools and information they need.

## Recommendation 4.1: Develop a comprehensive outreach strategy to educate all stakeholders about sea level rise.

A comprehensive outreach strategy should be developed to increase stakeholders' understanding of sea level rise, its effect on many aspects of life and ways to reduce these impacts. A strategy may include consideration of the best ways to reach different audiences. Education efforts should include both year-round and seasonal residents, children, government officials, businesses, commercial property owners, farmers, real estate agents, insurance agents, utilities and industries so that informed decisions can be made in the future, Increased education could engage more agencies, increase funding opportunities and result in support to help integrate sea level rise into long-range management plans, gain acceptance of the management decisions made, and possibly influence legislative decision making. In addition, providing information about other successful sea level rise adaptation programs and initiatives may further increase Delaware's acceptance of sea level rise and adaptation strategies.

### Recommendation 4.2: Provide education and outreach for impacted communities and citizens.

Communities that may be the most impacted by sea level rise should be provided with up-to-date information on sea level rise scenarios and be informed of adaptation measures that can reduce the impacts on their homes and communities. Residents of these areas should be made aware of available information about long-term and short-term adaptation measures, benefits and risks of various adaptation measures, combinations of risk factors (e.g., drainage and stormwater, coastal storms and sea level rise), and changes occurring in the insurance industry that may impact insurance availability and cost.

### Recommendation 4.3: Improve the ability of homebuyers to investigate a property's potential vulnerability to sea level prior to purchase.

Homebuyers' access to information about future sea levels should be improved through development of a comprehensive website that illustrates current flooding and future sea level rise inundation risks. In addition, prospective homeowner understanding of flood risks should be improved through increased interactions with local municipal planners. For example, the city of Newark has a successful program where prospective homeowners meet with land use planners prior to their purchase to review the property and surrounding land uses. A similar model could be employed in other municipalities to include sea level rise information.

### Recommendation 4.4: Provide targeted outreach to water and wastewater operators and water utilities.

Opportunities exist to reach out to state, municipal, county and private water and wastewater associations, such as the Delaware Rural Water Association and the Delaware Onsite Wastewater Recycling Association. These conferences are key venues for disseminating information on sea level rise, engaging stakeholders and experts in planning for its impacts, and evaluating preferred adaptation options and strategies to meet long-term goals.

Objective 5: Improve the Availability & Robustness of Sea Level Rise Data Sets While numerous tools have been developed that will assist individuals, communities, businesses and governments to adapt to sea level rise, several significant data gaps still remain. In many cases, adequate adaptation planning can occur with the existing information and tools, however the following 18 recommendations aim to improve the scale at which adaptation planning can occur and to improve the tools available to incorporate storm surge and precipitation concerns into inundation models.

## Recommendation 5.1: Improve monitoring of current sea level conditions and improve predictions for timing of inundation.

The number of monitoring stations should be expanded to improve the sea level rise data currently being collected. Increasing the number of tide gauges along the coast of Delaware would provide widespread water level data needed to refine model projections of inundation and our ability to identify potential risks on small spatial scales. Increased monitoring should include more information on changing landscapes, including agricultural lands and wetland areas.

### Recommendation 5.2: Install additional water level and salinity observational stations in Delaware's tidal waters.

Variations in salinity and tidal levels in the Delaware Bay and inland waters can be highly localized. The number and location of existing water level and salinity observation stations in Delaware are inadequate to understand site-specific conditions. Such stations can help with understanding the extent and frequency of storm flooding in the short term while providing data and information useful for planning adaptation responses. A report entitled, A Data GAP Analysis and Inland Inundation Survey for the Delaware Coastline, recommended additional stations in the vicinity of Slaughter Beach, Longneck, the city of New Castle, Woodland Beach and Port Mahon (Leathers et al., 2010).

### Recommendation 5.3: Improve the accuracy of Delaware's elevation benchmark network.

Delaware's network of benchmarks used for elevation surveys are currently inadequate due to lack of coverage in key coastal areas and problems with the accuracy of existing benchmarks. Existing benchmarks should be re-surveyed and additional benchmarks created. This is necessary to ensure that adaptation projects in coastal areas are designed and constructed with accurate elevation data.

### Recommendation 5.4: Continue and expand studies regarding sediment accretion rates

and susceptibility of wetlands to sea level rise. The state, University of Delaware and the National Estuary Programs have been working together to study and monitor sediment accretion rates and plant composition in Delaware's marshes in order to better understand susceptibility of certain marshes to inundation from sea level rise. Expanding this work to targeted additional locations across the state will provide a better data set from which to base land acquisition, restoration and retreat decisions.

## Recommendation 5.5: Conduct research to better understand human response to sea level rise and adaptation.

People are the core of any decision about adaptation measures, yet there are currently only a few studies about coastal residents' opinions of adaptation actions, thresholds for action and likely emotional responses to flooding and inundation. A better understanding of coastal residents' attitudes, perceptions and motivations could be very helpful in working with communities to choose adaptation options.

### Recommendation 5.6: Develop sea level models that incorporate storm surge impacts.

Sea level rise can exacerbate the effects of storm surges. The current sea level rise vulnerability assessment is based on a bathtub model, where the extent of inundation is estimated based on mean higher high water (MHHW) and land elevations. This model does not yet incorporate storm surges due to the complexity of accurately modeling storm surge at a statewide level. However, a storm surge model that takes into account future sea levels would provide a tool to better plan for inundation impacts.

### Recommendation 5.7: Conduct a risk assessment for Delaware's system of dikes & levees.

Dikes and levees act to protect infrastructure, natural resources and private property from flooding during storms and extreme high tides. An inventory of the dikes and levees in the state should be conducted to determine which ones are most at risk, including a specific analysis of each dike for possible future risks posed by sea level rise, storm surge and stormwater. This would lead to a risk analysis to evaluate if there is an escalating risk from the projected sea level rise scenarios discussed in the vulnerability assessment.

### Recommendation 5.8: Encourage federal agencies to integrate sea level rise planning into their flood models.

The National Flood Insurance Program and Federal Emergency Management Agency do not currently include consideration of sea level rise in their floodplain models, which are based upon historic storm and flood data rather than future projections. This results in floodplain maps that may underrepresent flood risk to residents. Delaware and other low-lying states can encourage the federal agencies to incorporate sea level rise into flood models and can provide data and local knowledge for the development of floodplain maps that include sea level rise.

### Recommendation 5.9: Model potential stormwater inundation problems in highly vulnerable areas.

Sea level rise may reduce the ability of stormwater to drain from an area if the outfalls are located on tidal water bodies or are linked to tide gates. This can worsen the effects of flooding from both heavy rainfall and storm surge events. Watershed scale or smaller models should be developed for a better understanding of flooding impacts from the combination of stormwater and higher tides.

# Recommendation 5.10: Develop a model that will predict changes to salinity in surface water that may occur under differing sea level rise scenarios.

Improving our understanding of sea level rise impacts resulting from migration of salt water into the Delaware River is necessary to better assess

risk to infrastructure, facilities and natural systems. Modeling can provide the information necessary to better anticipate impacts to natural systems and develop an understanding of the different threshold of these systems. This could be done on a smaller watershed scale using nested models.

### Recommendation 5.11: Develop a statewide groundwater model.

A general, screening-level groundwater computer model can provide information on how ground-water movements and water table levels may be impacted by sea level rise. This data would provide the necessary information needed to understand which industries and businesses may be at risk from corrosion, which contaminated sites may be at risk, and which habitats may be threatened. Site specific evaluations may be necessary, but an improved understanding of overall sea level rise impacts to the water table is required to better assess risk.

## Recommendation 5.12: Develop and maintain a comprehensive database that contains the location and condition of all wastewater infrastructures.

The vulnerability assessment analyzed public wastewater facilities and pumping stations: data regarding private or community systems, pumping stations and pipelines are not available in a consolidated format. This information should be entered into a comprehensive database and routinely updated to plan more accurately for sea level rise impacts to wastewater systems and to identify opportunities to integrate services in vulnerable areas with systems that may be more reliable over time. The database should include a condition assessment of the facility in order to plan for anticipated maintenance and upgrades. It should also triage areas for repairs and relocation to expedite the process when funds are available.

### Recommendation 5.13: Identify and preserve areas for potential wetland migration.

As coastal wetlands become permanently inundated, it is vital to facilitate the landward migration of these habitats to maintain their valuable functions. Available geographic information system (GIS)

data can help identify lands adjacent to wetlands that have the potential to accommodate future marsh migration. Criteria should be developed to prioritize lands for acquisition or permanent conservation easements. As an example, areas that are undeveloped or lack barriers such as major transportation routes or other infrastructure woul more easily accommodate wetland migration. Also agricultural land that is no longer productive due to salt-water intrusion may better accommodate future wetland migration. Areas identified as suitable for potential migration and the means to prohibit structures or obstructions in these areas should be thoroughly evaluated.

#### Recommendation 5.14: Identify the data

necessary to plan transportation investments. Roads and bridges that are located in areas that are expected to have flooding issues as illustrated through the inundation models in the vulnerability assessment should be specifically identified. Routes should then be prioritized based on: system performance, age and condition, lifespan, origin and destination, replacement schedule, adjoining land use (both present and future), and choke points. Sea level rise inundation scenarios should be incorporated into the existing mechanisms used by DelDOT to prioritize projects.

## Recommendation 5.15: Increase understanding of the regional implications of loss of industrial areas in coastal Delaware. Reduction in capacity at power generating facili-

Reduction in capacity at power generating facilities and ports may have regional implications for the electrical grid as well as availability of goods and services. In order for businesses to make wise decisions about future investments in their coastal industrial properties, additional information will be needed about impacts to other facilities throughout the region.

### Recommendation 5.16: Improve understanding of impacts to adjacent properties from adaptation actions.

Certain adaptive measures taken to mitigate the impacts of sea level rise may have unforeseen secondary and cumulative impacts to adjacent properties. For example, the hardening of a segment of shoreline with rock can result in

accelerated erosion of adjacent unprotected shorelines. Understanding the complex impacts of various adaptive measures will help guide more effective adaptive response plans.

# Recommendation 5.17: Encourage the development of a research and policy center at a university or college campus that would focus on applied research for sea level rise and adaptation.

There are many regional data gaps related to sea level rise. Filling these gaps through collaboration with networks of university researchers and policy analysts would improve adaptation planning efforts. It may be worthwhile to provide incentives to university researchers to address these topics. Developing clear statements of research needs may improve the academic community's ability to obtain grant funding for research.

# Recommendation 5.18: Foster pilot projects that demonstrate the effectiveness of best management practices for management of agricultural lands affected by sea level rise.

Pilot projects to demonstrate or to study the effectiveness of best management practices could be used to provide guidance to land managers to better adapt to sea level rise. These projects would provide insight on the effectiveness of the adaptation strategy and provide information on the associated costs.

#### Objective 6: Provide Technical Assistance to Partners for Assessing Vulnerability and Choosing

Adaptation Strategies
Although information, data, and planning tools exist for those wishing to incorporate sea level rise into their decisions or plans, the information can be difficult for non-technical audiences to interpret and use. These datasets are also continually being updated and refined. In recognition of these complexities, the following five recommendations are aimed at providing a central entity for distribution of sea level rise information, ensuring that technical assistance is available and providing a variety of tools for decision-making.

### Recommendation 6.1: Create a coordinated effort to provide technical assistance to local governments.

Municipal and county governments may not currently have the staff resources, technical capability or funding to plan for and adapt to sea level rise. There is no one coordinated entity that is providing coastal hazard and sea level rise assistance to municipal governments. The DNREC Delaware Coastal Programs provides technical assistance and grant funding annually. The University of Delaware Sea Grant College Program provides technical assistance through its Sustainable Communities Program. The Office of State Planning and Coordination provides technical assistance to communities conducting comprehensive development plan revisions, as does the University of Delaware's Institute for Public Administration. The DNREC Shoreline and Waterway Management Program provides assistance to communities to develop floodplain regulations and receive discounted flood insurance rates through the Community Ratings System. A coordinated effort by these (and other) entities could result in consistency among local jurisdictions and ensure that all municipal governments wishing to plan for coastal hazards and sea level rise have an opportunity to obtain the technical assistance they need. It could also result in coordinated grant funding opportunities for municipalities.

# Recommendation 6.2: Provide land managers, fisheries managers and farmers with the information and extension support necessary to manage lands and fisheries in areas affected by sea level rise. Technical assistance for land managers and

recnincial assistance for land managers and agricultural producers is needed to disseminate information about salt-water intrusion into irrigation wells, salt tolerant plant species, and best management practices (BMP) for land in transition due to changes in water level or salinity. University extension agencies, or other established programs such as the Natural Resource Conservation Service, could be encouraged to provide this service. An additional goal might be to foster pilot projects to demonstrate or study the effectiveness of BMPs.

# Recommendation 6.3: Provide technical assistance for industrial and port facilities to incorporate sea level rise into investment plans and continuity of business plans.

Facilities often have robust continuity plans where they address interdependencies, but no inventory of these plans has been conducted. Sea level rise could be incorporated into these plans to ensure facilities are resilient to the impacts of storm surge coupled with sea level rise. Technical assistance could be provided through one-on-one outreach or through databases and information clearinghouses.

### Recommendation 6.4: Develop best management practice manuals for adaptation in Delaware.

Adaptation measures will be implemented by a variety of stakeholders including municipal and county governments, state government, businesses and individuals. A set of best management practices (BMPs) should be provided for their use and reference. BMP manuals could be created for several different topics including infrastructure siting, residential development, and natural lands management. Manuals should be based upon successful strategies employed by other states, non-profits and the private sector and could be developed in cooperation with local colleges and universities. A toolbox for adaptation could also be created that would highlight successful policies in other states.

## Recommendation 6.5: Develop a database of costs of adaptation options for use by decision-makers and the public.

Such a database should include examples of the costs of elevating buildings, beach nourishment, abandoning buildings, elevating roadways, building hardened shorelines, elevating and repairing dikes, and constructing living shorelines. Cost estimates cannot be site-specific but may be able to provide general guidelines. This database should also incorporate cost benefit analyses that would evaluate retreat, accommodation, avoidance and protection measures, including return on investment.

#### Objective 7: Expand Funding Opportunities for Adaptation Planning and Implementation Projects

Sea Level Rise Advisory Committee members, public engagement session attendees and stakeholder groups consulted during the development of these recommendations had many questions about what it would cost to adapt to sea level rise. There were also many concerns about whose responsibility it is to pay for adaptation and whether funds are (or would be) available. In addition, there were many concerns regarding fairness and equity of funding for adaptation22. The Sea Level Rise Advisory Committee recognizes the critical importance of these funding issues, but feels it did not have enough information about potential costs of adaptation in Delaware to make specific recommendations about new or amended funding sources. The following recommendation is intended to be a starting point for a comprehensive investigation into funding options that can be considered for implementation as adaptation costs become apparent.

#### Recommendation 7.1: Convene an expert panel to provide an assessment and analysis of funding options for adaptation measures.

At the current time, there is little specific infor-mation available regarding the potential cost of on-the-ground adaptation measures in Delaware. Because costs are unclear, it is difficult to recommend a particular course of action. An expert panel should be brought together to investigate the suite of options that are available to state and local governments and individuals to fund future adaptation measures. Included in this analysis should be traditional revenue generators such as taxes and fees, but it should also include innovative funding mechanisms such as special tax districts, incentives and cost-share programs. The analysis should utilize the preliminary funding options formulated by the Sea Level Rise Advisory Committee and public comments received during the Adaptation Engagement Sessions as a baseline23.

<sup>22</sup> Many of these concerns are reflected in the Guiding Principles listed in Chapter 3.

<sup>&</sup>lt;sup>21</sup> See Appendix E for comments received by the public and Appendix I for a list of the preliminary funding options created by public comments and the advisory committee.

### Chapter 7: Next Steps for Adapting to Sea Level Rise

The Delaware Sea Level Rise Advisory Committee was established to make recommendations about adapting to sea level rise in Delaware, but not to implement them. With the completion of this document, the Sea Level Rise Advisory Committee will be disbanded and the DNREC Delaware Coastal Programs plans to lead implementation efforts, in coordination with willing partners.

#### Dissolution of the Sea Level Rise Advisory Committee

The completion of this document represents the conclusion of the work of the Delaware Sea Level Rise Advisory Committee, which was convened to develop recommendations, but not to implement them. The advisory committee was convened in November, 2010 and participated in a final document signing ceremony in August, 2013. During that time, the committee held 20 advisory committee meetings, numerous ad-hoc committee and workgroup meetings, 6 focus groups, and 8 public engagement sessions. Advisory committee members have spent countless hours in support of their goal, provided valuable insights and expertise and successfully fulfilled their obligation.

#### Implementation Workshop

Time, staff and funding constraints prevented the Sea Level Rise Advisory Committee from prioritizing the recommendations and from gathering more specific information about each one, such as how much implementation would cost, the specific steps required to implement and identification of a willing lead entity. However, such information will be necessary in order to begin implementing many, if not all, of these recommendations.

The Delaware Coastal Programs section of the DNREC has committed to hosting a stakeholder

workshop in 2014 to answer these, and other questions about each recommendation. Similar workshops have been successfully held in the past to discuss ideas and recommendations. The result of this workshop would be a list of priority recommendations for implementation, Workshop participants and others will help develop each recommendation into a small proposal, including cost estimates, activities and the groups, organizations or agencies necessary to implement.

#### Establishing an Implementation Team

Once specific details about each recommendation have been developed, the Delaware Coastal programs will put together an informal implementation team that will focus on coordinating to secure funding and resources for priority recommendations. It is also anticipated that some of the recommendations can be implemented without additional funding or coordination. See Appendix H for resources useful for implementation.

#### $Implementation \, of \, Adaptation \, Measures$

Adaptation planning and selection of adaptation measures at the parcel, local or agency level will occur in parallel to state efforts to implement the 55 recommendations of the Sea Level Rise

Advisory Committee. Although implementation of the recommendations will improve Delaware's ability to adapt in the future, technical assistance and grant funds are available now from a variety of sources to assist those wishing to proactively address sea level rise.

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# Appendix A: Vulnerable Resources Affected by Recommendations

While a few of the 55 recommendations of the Sea Level Rise Committee are specific to one or two vulnerable resources, many address adaptation capacity building for a number of vulnerable resources. The chart contained in this appendix illustrates the breadth of the recommendations by indicating those resources that will be affected by implementation of each recommendation. This chart can be used as a guide by those wishing to consider actions for specific resources.

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### Appendix B: Dissenting Opinions

1600 N. Little Creek Road Dover, DE 19901-4706 Telephone: 302-678-1520 Fax; 302-444-8068 info@hbade.org www.hbade.org



Frederick T. Fortunato President

Howard Fortunato

Executive Vice Presider

SERVING DELAWARE SINCE 1947

August 9, 2013

Susan E. Love via email susan.love@state,de.us Delaware Coastal Programs 5 East Reed Street, Suite 201 Dover, DE 19901

RE: Sea Level Rise Position Statement

Dear Susan

Thank you for the opportunity to participate in the Sea Level Rise Committee. The Home Builders Association of Delaware (HBADE) is committed to short and long term statewide planning for storm emergencies and science-based sea level rise.

HBADE is a housing and business advocacy association representing more than 400 Delaware businesses with nearly 8,000 employees. As such, we are committed to creating a business friendly and vibrant economy for our state. By necessity our association is a professional volunteer organization that now spends the bulk of our volunteers' time reviewing DNREC proposed and enacted regulations — much more than changes for all other State and County bodies. The recent increase in DNREC regulatory proposals, from sea level rise, storm water management regulations, flood plain, to Energy Code, and Watershed Implementation Plans have far reaching unintended consequences to Delaware's economy. These unintended consequences of DNREC actions are directly related to Delaware's struggling economy, business and job growth, and real estate values. Although the housing economy is improving, growth is slow and can easily be upset by numerous changes to the local community.

The Delaware Sea Level Rise Advisory Committee "Committee" has developed a recommendation report "Recommendations for adapting to Sea Level Rise in Delaware," in which it provides a series of environmental problems that may result from possible sea level rise within the next 100 years. As such the Committee has provided Delaware with a series of preferred adaptation strategies that can be used to adapt to – and mitigate for – potential sea level rise. While HBADE is committed to working with the State to ensure there is rounded discussion of issues and impacts, we are concerned with several determinations that have come out of this research. We believe no action should be taken on recommendations without full review by the public and the Delaware General Assembly. It is unclear if DNREC is authorized to take any action under the Delaware Code.

Our concerns begin with the ongoing effort by the State to portray Delaware to have 3' -Our concerns begin with the ongoing eitor by the State to portray Delaware to have 3° (1 - 1.5 meters) - of sea level rise by 2100 and the resulting negative economic impact of using the unscientific and faulty models of measurements. Based upon the information produced by the SLR Committee, it is evident that DNREC's approach will stigmatize our Delaware coastal areas and cost citizens of Delaware greatly for an event that current science indicates may not happen over the course of 87 years. This includes changing how communities are planned, financed and developed, mortgage financing requirements, payments of additional flood insurance, loss of ability to construct or sell homes in the stigmatized areas assumed to be, and identified as being subject to sea level rise, and changing how infrastructure is invested in areas assumed to be below the rise levels. Is it worth the cost to our local economy to have the State and their scientific agency (DNREC) promote the permanent flooding of 11% of the States land, which is equivalent to 20,000 dwellings lost, the loss of all state tidal wetlands and the loss of

Current scientific data shows 12" of sea level rise during the last century. This data now shows a slight increase and projection of 13" of sea level rise this century. HBADE understands that the environment is ever changing and is dedicated to Statewide planning for 19.5" (.5 meters) of sea level this Century which equals 50% more rise than what current science shows. We also stand behind the effort for continued monitoring of this issue and adapting programs, policies and other efforts as data changes.

Unfortunately, since Delaware is utilizing planning for worst case scenarios, rather than implementing an adaptive management approach to possible sea level rise, we feel the current path taken will lead to the destruction of the Delaware coast and its economy.

We request the State discontinue an opinion-based narrative and web site describing the Delaware coast to be under water. The degree of sea level rise is a projection and is not based on conclusive and universally agreed comprehensive science. As such Delaware must be cautious with accepting positions and policies that unduly impacts the State's economics while yielding minimal environmental benefit. HBADE is thankful for the opportunity to comment on this issue and our membership is more than willing to discuss these concerns in more depth at your convenience.

Very truly yours,

Howard Fortunato Executive Vice President

Kevin Whittaker Keith Rudy



#### MINORITY STATEMENT BY THE LEAGUE OF WOMEN VOTERS OF DELAWARE FOR THE SEA LEVEL RISE ADVISORY COMMITTEE ADAPTATION REPORT

As with the earlier Vulnerability Assessment Report, the staff of DNREC's Coastal Programs did a good job of leading the Sea Level Rise Advisory Committee in its work to develop the Adaptation Report, incorporating many of the comments and suggestions suggested by members of the Committee and the public. There was, however, one important issue on which we were not able to get the agreement of a majority of the Committee. That issue is disclosure. The League's alternate recommendation follows:

Require disclosure of the risks of sea level rise and storm surge in the sale of all real property, as well as the cost and availability of federal flood insurance.

The committee has agreed that homebuyers' access to information about future sea levels be improved through development of a comprehensive website that illustrates current flooding and future sea level rise inundation risks. The League would add storm surge to "information about future sea levels."

The League would greatly strengthen the force of the Committee's recommendation by requiring disclosure of the risks of sea level rise (and storm surge), as well as cost and availability of flood insurance, rather than simply making the information available if a potential buyer searches for it. We recognize that disclosure of location in a flood plain is currently required. We further recognize that because of the risk of property loss in the event of sea level rise and storm surge and greatly increased premiums for flood insurance, not to disclose these risks could lead to great economic loss to buyers. To fail to require disclosure is to fail to provide what may be the low-lying fruit in Delaware's adaptation strategies; "avoidance." Without such disclosure a family could unwittingly purchase a home today in a quintessentially vulnerable community, such as Prime Hook, thereby not only putting that family at risk but possibly also putting the citizens of Delaware at risk to pay for damages when the next storm comes.

Charlotte (King LCT)
Charlotte King, President, LWVD

Chart (of man Chad Tolman, Climate Change Chair, LWVD

July 26, 2013

#### POSITIVE GROWTH ALLIANCE

Po Box 1145 • Millsboro, DE 19966 • Phone 302-934-1227 • Fax 302-934-1933

August 14, 2013

### Minority Report on Recommendations of the Sea Level Rise Advisory Committee

Even though the Positive Growth Alliance had a seat on the Delaware Sea Level Rise Advisory Committee, we have many deep concerns about the both the recommendations in the report and the sea level rise predictions we were forced to accept as fact. These concerns forced us to vote against many of the formal recommendations.

#### On predictions of .5, 1, and 1.5 meter levels of sea level rise by 2100

Daily, there are new reports coming out, including from the U.N., that the earth has not warmed for approximately 15 years. In fact, climate models are being revised to try and accommodate this apparently unexpected situation.

It is no surprise to us that 100 year climate predictions based on computer models are difficult. What is surprising is that our small state has chosen to put its economy at risk on the basis of such predictions.

Many of the recommendations in this report could lead to action in the near future that will have immense economic consequences, yet it will not be known if those actions are truly necessary for decades. For most human interactions with sea level rise, remaining flexible and taking action when the need clearly presented itself has been an effective and profitable tactic since before the founding of our nation. No convincing evidence has been presented to us that would negate this strategy as the best overall course for the future.

Can government be trusted to make accurate predictions of the future?

We do not believe that government can predict the future any better than those outside of government. In fact, because of the effect of politics, government's predictive ability is almost surely considerably worse.

In the real world, most decisions are based on economic necessity. In addition, those actions usually affect only the entity making the decision. Private interests have little or no ability to compel the behavior of

While hard economic choices certainly play a role in government decision making, small but powerful special interests with strong political connections often prove to be far more influential.

For example, there are special interests with an agenda of stopping development. Parts of this Sea Level Rise report could be utilized by these groups to prevent others from using their private properties. The arguments typically made by these interests often do not take economic realities into account.

## Have government proposals for restrictive regulations always been supported by actual results? Decisions made in the private economy are judged very quickly by actual results. If actions are taken that turn out to be incorrect, either adjustments are made or bankruptcy or liquidation will occur.

On the other hand, poor decisions by government lead to reversals of policy only with great difficulty. Once rights are lost, they typically stay lost. Money lost is made up by the taxpayers.

As an example, just a few years ago, DNREC published a regulation that would have established a limited use zone of 120 acres around every eagle's nest. While this regulation was killed due to resistance by the public, DNREC now tells us that the Nanticoke River basin has the bighest concentration of bald eagles in the northeastern United States, with phenomenal nesting success.

If that regulation had actually been imposed, which DNREC said at the time was necessary for eagle protection, thousands of acres would have been placed off limits for use by their private owners, as well as the public, at the whim of an eagle establishing a nest. The passage of time has shown that DNREC was wrong about the need for this regulation. Similarly, we believe that this document could well lead to the imposition of many regulations in regards to sea level rise that could turn out to be totally unwarranted, but that will likely cause great economic harm and loss of property rights.

#### Comments on selected specific recommendations

- 1.1 Coordination between government agencies is typically for the benefit of the agencies and to the detriment of citizens. Most decisions should be made by an elected government as close to the voters as possible. This government entity will be more likely to understand that it has an obligation to represent its constituents' concerns, rather than a few special interests which are politically connected. In cases that involve land use, the state constitution and state law actually designates county and municipal governments as the prime decision makers and other government agencies should not have veto power over their decisions.
- 1.4 The future is too unpredictable to require planning for sea level rise at this point. The fact that flood insurance claims are incredibly low (according to FEMA, every claim made from 1978 to 2010 is paid for with 1.2 years of premium) tells us it is not time to further restrict property owners beyond current flood insurance requirements.
- 1.7 If this is a recommendation for more regulation, we are opposed.
- 2.1 There is not enough information available at the present time to create new incentives related to SLR.2.2 Too many government decisions are being mde by regulators rather than elected officials. The General
- Assembly should play a role in any SLR requirements that require overall government action.
- 2.4 Septic systems and wells are perfect vehicles for government agencies to impose political agendas on landowners. An example is when DNREC tried to deny a central sewer permit for a proposed development near Leipsic based on sea level rise before there were any regulations at all. The landowner was forced to go to court to get a permit.
- 2.5 These sewer facilities are mostly privately owned. It should only be done with the full cooperation of the private owner.

- 3.1 This another opportunity for non-elected government officials to impose their political agendas on citizens with little opportunity for accountability.
- 3.6 It is difficult enough to predict rapidly changing traffic conditions without having to take into account changes that will take place over decades, if ever.
  3.14 We simply do not have enough hard evidence to develop a retreat strategy at this time.
- 4.1 There is not enough hard evidence to justify indoctrinating our children and the public at this time.
  5.1 We strongly agree with this recommendation. It should be listed first as 1.1.
  5.2, 5.3, 5.4 We agree with all. In general, section 5 should be changed to section 1.
- 5.5 We agree with this only if it includes strong considerations for the rights of Delaware citizens.
- 5.8 We strongly disagree because Delaware flood insurance policy holders are currently being dramatically overcharged for the risk of flooding in Delaware as proven by FEMA loss records.
   5.13 We are concerned this recommendation could have a heavy negative impact on personal property

In conclusion, we are very concerned that the work of the Sea Level Rise committee could be used to cause great economic harm to the citizens of Delaware. There is no doubt in our minds that this document will be used as the basis of creation for many new regulations over the next few years.

Economic trends are moving in the wrong in direction in our state. The U.S. Department of Commerce has announced that Delaware is now second to last among the states in economic growth. In addition, they also state that personal income has declined from  $19^{th}$  to  $23^{cd}$  among the states in the last four years. This is ample warning that Delaware should get its economic house in order before considering new, opportunity-killing restrictions based on sea level rise.

Sincerely,

Richard Mollins Executive Director

### Appendix C: Sea Level Rise Advisory **Committee Members**

The following is a list of the 24 members and organizations of the Delaware Sea Level Rise Advisory Committee. The list is alphabetical by organization. Where tenure on the committee was shared by two individuals due to organizational changes or retirement, two names appear above the organization. In addition, designation nated alternates for each committee member are listed.

John Taylor Delaware Chamber of Commerce Delaware Public Policy Institute

#### Mark Davis

Delaware Department of Agriculture Office of the Secretary

#### **Kurt Reuther**

Delaware Department of Homeland Security Alternate: Don Knox

#### Dr. Richard Perkins

Delaware Department of Health and Social Services Division of Public Health

#### Barbara DeHaven

Delaware Economic Development Office

#### Pamela Bakerian

Delaware Farm Bureau

#### The Honorable Quinton Johnson

Delaware House of Representatives

#### Lorilee Harrison/Karen Weldin Stewart

Delaware Insurance Commissioner's Office

#### Dr. Chad Tolman

Delaware League of Women Voters Alternate: Peggy Schultz

Brenna Goggin Delaware Nature Society

#### Ruth Ann Jones

**Andrea Godfrey**Delaware Office of Management and Budget Budget Development, Planning and Administration Alternate: Rebecca Steel

#### Constance Holland

Delaware Office of Management and Budget Office of State Planning Coordination

#### William Lucks

Delaware Realtor's Association

#### Michael Kirkpatrick

Delaware Department of Transportation Office of Planning Alternate: Robert McCleary

#### Sarah Cooksey

Delaware Department of Natural Resources and Environmental Control Office of the Secretary

**Keith Rudy** Homebuilders Association of Delaware *Alternate: Kevin Whittaker* 

Mary Ellen Grey Kent County Department of Planning Alternate: Sarah Keifer

Victor Letonoff Lewis Killmer Delaware League of Local Governments

Karl Kalbacher Marcus Henry New Castle County Department of Economic Development Alternate: Michael Bowser

Richard Collins
Positive Growth Alliance

Jeff Shockley Sussex County Planning and Zoning Office

Richard Jones The Nature Conservancy

Jerry Esposito
Tidewater Utilities, Inc.

Dr. Chris Sommerfield

University of Delaware College of Earth, Ocean and the Environment

### Appendix D: Adaptation Focus Group **Attendees**

In October, 2012 six stakeholder focus group sessions were held to develop a list of actions that could be taken to improve Delaware's capacity to adapt to sea level rise. The focus groups centered on the high and moderate concern resources. Attendees are listed below alphabetically.

#### Coastal Defenses Focus Group Attendees

Jeff Bergstrom City of New Castle

**David Carlson** 

Delaware Department of Homeland Security Delaware Emergency Management Agency

Sarah Cooksey

Delaware Department of Natural Resources and Environmental Control Office of the Secretary

Ron Hunsicker

Town of Bowers Beach

**Jim Kirkbride** Pickering Beach

Jim Laird

Dewey Beach

Frank Piorko

Delaware Department of Natural Resources and Environmental Control Division of Watershed Stewardship

**Tony Pratt** 

Delaware Department of Natural Resources and Environmental Control

Division of Watershed Stewardship

Kash Srinivasan

City of Wilmington Department of Public Works

Scott Thomas

Southern Delaware Tourism Bureau

David Twing
Delaware Department of Natural Resources and Environmental Control Division of Watershed Stewardship

Industrial Land Use Focus Group Attendees

David Bacher

Delaware Department of Natural Resources and Environmental Control Division of Waste and Hazardous Substances

Delaware Department of Natural Resources and Environmental Control Office of the Secretary

#### 385

Barbara DeHaven

Delaware Economic Development Office

Rebecca Gudgeon Delaware City Refinery

Tom Heck Delaware Solid Waste Authority

Cheryl Hess

Calpine Corporation

Randall Horne

Diamond State Port Corporation

Karl Kalbacher

New Castle County Economic Development Office

**Kurt Reuther** 

Delaware Department of Safety and Homeland Security

Stu Widom

Calpine Corporation

Land Preservation and Habitat Focus Group Attendees

Partnership for the Delaware Estuary

Sarah Cooksey
Delaware Department of Natural Resources
and Environmental Control
Office of the Secretary

Robert Coxe

Delaware Department of Natural Resources and Environmental Control Division of Fish and Wildlife

Andrea Godfrey

Delaware Office of Management and Budget

Virgil Holmes

Delaware Department of Natural Resources and Environmental Control Division of Water

Ron Hunsicker Bowers Beach

Richard Jones

The Nature Conservancy, Delaware Chapter

Delaware Department of Natural Resources and Environmental Control

Division of Fish and Wildlife

Jim Kirkbride Pickering Beach

Dr. Chris Sommerfield

University of Delaware

College of Earth, Oceans and the Environment

Bart Wilson Center for the Inland Bays

Land Use Focus Group Attendees

Rick Allen

Alliance of Bay Communities

Brooks Cahali

Delaware Department of Natural Resources

and Environmental Control

Division of Watershed Stewardship

Rich Collins

Positive Growth Alliance

Mark Davis

Delaware Department of Agriculture

Mary Ellen Grey Kent County Department of Planning

**Lorilee Harrison**Delaware Department of Insurance

Constance Holland

Delaware Department of Management and Budget Office of State Planning Coordination

#### 386

The Honorable Quinton Johnson

Delaware House of Representatives

Victor Letonoff

Delaware League of Local Governments

Guy Phillips Delaware Farm Bureau

Michael Powell

Delaware Department of Natural Resources and Environmental Control Division of Watershed Stewardship

Thomas Powers

University of Delaware Center for Science, Ethics and Public Policy

Keith Rudy Homebuilders Association of Delaware

**Chad Tolman** Delaware League of Women Voters

**Richard Wilkins** 

Delaware Farm Bureau

Transportation Focus Group Attendees

Rick Allen

Alliance of Bay Communities

**Barry Benton** 

Delaware Department of Transportation Division of Transportation Solutions

Delaware Department of Natural Resources and Environmental Control Division of Watershed Stewardship

Silvana Croope Delaware Department of Transportation Transportation Management Center

Jennifer DeMooy

Delaware Department of Natural Resources and Environmental Control

Division of Energy and Climate

Gene Donaldson

Delaware Department of Transportation Transportation Management Center

Rob McCleary

Delaware Department of Transportation Division of Transportation Solutions

Cathy Smith

Delaware Transit Corporation

Water and Wastewater Focus Group Attendees

Jerry Esposito

Tidewater Utilities

Matthew Miller City of Wilmington Department of Public Works

Doug Rambo

Delaware Department of Natural Resources and Environmental Control Division of Water

Davison Mwale

Delaware Department of Natural Resources and Environmental Control Office of the Secretary

Dave Schepens
Delaware Department of Natural Resources and Environmental Control Division of Water

Stewart Lovell

Delaware Department of Natural Resources and Environmental Control Division of Water

Hillary Moore-Valentine

Delaware Technical and Community College

Delaware Department of Natural Resources and Environmental Control Division of Climate and Energy

**Dr. Chris Sommerfield**University of Delaware
College of Earth, Oceans and the Environment

**Dr. Richard Perkins**Delaware Department of Health and Social Services
Division of Public Health

### Appendix E: Public Comments

The Sea Level Rise Advisory Committee held three public engagement sessions to solicit feedback on 61 Options for Adapting Delaware to Sea Level Rise (Options), the precursor to the final 55 recommendations contained within this document. A comment form was provided to all public engagement session participants; these forms were submitted in-person, via email and via US mail. In addition, the comment form was available to fill out online. A total of 57 comments were received. All comments received were compiled, summarized and reviewed by Sea Level Rise Advisory Committee members. A summary of these comments is below. Please note that the numbering scheme changed when the recommendations were finalized. Comments specific to funding options can be found in Appendix I.

This Appendix provides only a summary of the comments received on the Options; full text of the comments received is available for viewing online at http://de.gov/slradaptplan. The comments appear online as received by the Delaware Coastal Programs office, however personal information has been redacted.

#### **Overarching Comments**

#### Organization and prioritization of options

Multiple comments were received requesting that the Options be reorganized and/or prioritized for the sake of clarity and to help with implementation.

There were several comments regarding how emission rates and global climate change are influencing sea level rise and storm surge. A more in-depth description of climate change, and Delaware's vulnerabilities associated with climate change, is currently being worked on by the DNREC Division of Energy and

#### Options vs. recommendations

Commenters were concerned that referring to the adaptation action items as "Options" would reduce the strength of the document and that they should be referred to as "recommendations." The term "Options" was utilized during the public sessions to imply that consensus had not been reached yet by the Sea Level Rise Advisory Committee.

#### Specific Comments about each Option

Comments received about specific options are summarized and/or directly quoted in bullet form in the following sections. The general number of supportive comments and non-supportive comments are also tallied. Please note that the options are numbered as they were presented at the public engagement sessions; the numbering scheme changed for the final document.

#### IMPROVE COMMUNICATION AND COORDINATION AMONG STATE, FEDERAL, LOCAL AND RE-GIONAL PARTNERS TO STREAMLINE SEA LEVEL RISE ADAPTATION EFFORTS

- 1. Conduct a comprehensive inventory of key funding, coordination, regulations and policies and analyze them for barriers and opportunities for sea level rise adaptation. There was support for this option. 10 commenters specifically supported it; 3 did not.
  - Comment to specifically prioritize a review and legal analysis of the Coastal Zone Act, Beach Preservation Act and Public Accommodations Tax
  - Several specifically wanted to prioritize this work
- 2. Increase opportunities for technology transfers and regional coordination for transportation issues affected by sea level rise. There was support for this option. 10 commenters specifically supported it: 2 did not.
  - Suggestion to include/highlight work that is already ongoing
- 3. Develop a Federal Highways Administration climate change framework. There was support for
  - this option; 8 specifically supported; 3 did not.

     Suggestion to also recommend use of pilot projects in this option
  - Suggestion to use this option to coordinate with others to determine what is essential to maintain roadways
- 4. Improve coordination of permit decisions for adaptation projects among federal, state and local officials. There was support for this with 15 specifically supporting; 2 not supporting.
  - · May wish to include "streamlining" into this option
  - · One commenter thought this should be prioritized
- $5. \ \ \textbf{Incorporate sea level rise into public and private sector regional planning efforts.} \ \textit{There was}$ support for this option; 15 in support; 2 not supporting.
  - At least 4 commenters thought this was very important/should be prioritized
     Comment to include the Port of Wilmington, USFWS Comprehensive Conservation Plans
  - and Office of State Planning Coordination in the text
  - Comment that this is critical to evacuations
- 6. Create new partnerships to increase resources for research and development of adaptation • Amend to include that is should also "enhance existing partnerships"
   • Include consultants as part of the partnerships to be developed.

  - Perhaps this should specifically call for pilot projects, rather than partnerships?
  - One commenter thought this was very important/priority
- 7. Provide sea level rise information to the Delaware Agricultural Land Preservation Program for consideration. There was support for this option with 8 specifically supporting and 3 not in support.

  • Question as to why this wasn't already happening.

  - Suggestion to also include the Nutrient Management Commission
     Comment that this might be more suited to the Technical Assistance section

- 8. Provide technical assistance to Delaware's Open Space Council for incorporating sea level rise into its criteria for acquisition of natural areas. There was support for this option with
  - 10 specifically supporting and 2 not in support.This has already occurred, should it be deleted and instead included as a success story?
  - Similar comments to Ag Land Preservation Program with respect to classification
- Encourage the establishment of a sea level rise group within American Association of State Highway Transportation Officials (AASHTO). There was support for this option with 7 in support and 3 not in support.
  - Commenter reported that there is already a Transportation Climate Change group in AASHTO
  - · AASHTO Climate group could be narrowed to SLR

#### PROVIDE INCREASED REGULATORY FLEXIBILITY FOR ADAPTATION AND IMPROVE CONSISTENCY AMONG REGULATORY AGENCY DECISIONS

- 10. Encourage early transportation planning and conceptual infrastructure design for sea level rise adaptation. There was support for this option with 10 specifically supporting and 1 not in support.

  Commenter thought that "encourage" is a wimpy word.

  - · Commenter thought this could be included with the executive order recommendation.
  - One commenter thought this should be prioritized
- 11. Allow for the connection of individual septic systems to community septic systems with excess capacity when human safety and welfare are at risk. There was support for this option with 9 specifically supporting and 1 not in support.
  - · No actionable comments, but one commenter reiterated that adequate ordinances at the county and municipal level are essential and questioned how the state/locals worked with respect to state guidelines and regulations and local ordinances.
- 12. Develop local land use ordinances that encourage consideration of the effects of sea level rise in the siting and maintenance of public infrastructure. There was support for this with 12 commenters specifically supporting and 1 not in support
  - One commenter reiterated that adequate ordinances at the county and municipal level are essential and questioned how the state/locals worked with respect to state guidelines and regulations and local ordinances.
  - One commenter pointed out that local governments would need lots of help
  - One commenter asked for a more robust way of enforcing the "guidelines" that this option discusses developing
  - · Several commenters pointed this out as very important or should be a priority
- 13. Consider sea level rise implications in future regulatory updates for septic systems and wells. There was support for this action with 9 specifically supporting and 1 not in support. No specific comments received.
- 14. Encourage the governor to sign an executive order that would direct state agencies to plan for sea level rise. This had support with 13 specifically supporting and 1 not supporting.
  - · Several commenters pointed out that this should be a priority and one of the first actions to be undertaken
  - One commenter thought there should also be a Cabinet level council established
     One commenter believed that the Executive Order would be inadequate; that a high level
  - official should be appointed to ensure implementation of SLR actions

- 15. Provide regulatory incentives that encourage sea level rise adaptation and that allow for innovative projects. There was support for this with 12 specifically in support and 2 not in support. One commenter thought this should be a priority. No other actionable comments received.
- 16. Evaluate the state Coastal Zone Act Regulations for changes that would increase flexibility for industries to adapt their shorelines and facilities to sea level rise. This had support, with caveats, with 10 specifically supporting and 3 not supporting.
  - There were several commenters who did not want to see this Act weakened and that they perceive that the Act is already too flexible in its interpretation.
    One commenter said don't weaken, but provide technical assistance
    One commenter wanted to require climate change impacts and sea level rise to be considered

  - in issuance of Coastal Zone Act Permits.
  - One commenter said that streamlining and increasing flexibility are good objectives.
- 17. Create a financial assurance program to minimize the state's liability to clean up industrial sites if they are abandoned as a result of sea level rise. This had support with 12 specifically supporting and 2 not in support.

  - One commenter wished to prioritize this option
    No other actionable comments received, though there were general comments reflecting concern for Burton Island landfill at the NRG Indian River Power Plant
- 18. Conduct a comprehensive update to the state's regulatory tidal wetlands maps and provide a way to periodically update the maps to reflect changes occurring from sea level rise.

  There was support for this option with 12 specifically commenting in support and 1 not in support.
  - Several commenters thought this should be prioritized
  - Several comments highlighted their desire to protect wetlands and the functions and benefits

#### PROVIDE CONSISTENT AND PREDICTABLE POLICIES FOR FUTURE GROWTH, INVESTMENT AND NATURAL RESOURCE MANAGEMENT

- 19. Incorporate sea level rise considerations into the Strategies for State Policies and Spending. There was support for this option with 12 specifically commenting in support and 3 not in support. Several commenters thought this should be prioritized.
- 20. Incorporate sea level rise considerations into municipal comprehensive development plans. There was support for this option with 14 specifically supporting and 3 not supporting.

  Many commenters thought this was very important and/or should be a high priority
- 21. Incorporate sea level rise into Delaware's Long Range Transportation Plan. There was support for this option with 11 specifically in support and 3 not in support.
  - · No actionable comments received
- 22. Incorporate sea level rise into the Transportation Operations Management Plan.
  - There was support for this option with 8 specifically in support and 3 not in support.
  - No actionable comment received
- 23. Encourage inclusion of sea level rise in Transportation Project Design Manuals.
  - There was support for this option with 7 specifically in support and 3 not in support.

    One commenter questioned whether AASHTO was already doing this.

- 24. Develop a statewide retreat plan. There was support for this option with 13 specifically supporting and 4 not in support.
  - · Several commenters thought that this was very important and/or should be a priority
  - · A good retreat plan updated periodically as the climate and sea level change might save wasted money and resources.
  - . Concern that this option and the entire section is a "kiss of death"
- 25. Conduct a legal review for disinvestment of publically owned infrastructure and privately owned buildings. Support for this option was mixed, with 7 specifically in support and 5 not in support.
  - One commenter thought that such a legal review must also include questions of "equal protection" and "environmental justice"
- 26. Consider use of a Transfer of Development Rights tool to direct future growth away from vulnerable areas. There was general support for this with 12 specifically in support and 4 not in support.
  - One commenter said "The development of innovative and flexible approaches for encouraging and incentivizing movement of property owners from vulnerable areas should be a priority. In addition to TDR's, new forms of buyouts that might include longer term and novel arrangements should be explored"
  - One commenter thought that TDRs would be difficult to implement
- 27. Develop a dike safety program. There was general support for this with 7 specifically supporting and 4 not in support.
  - One commenter thought this was very important, but that the write-up lacked the sense of urgency that it should have.
  - · One commenter wanted it to mention that this would likely require legislative and/or executive action
  - One commenter thought that it would just be more bureaucracy
- 28. Designate shoreline zones for adaptation action. There was mixed support for this,
  - with 6 specifically supporting and 3 not in support. One commenter guestioned if urban shorelines would be included
  - One commenter mentioned the strong link with the Bayshores Initiative
- 29. Develop comprehensive wetlands restoration strategy in response to sea level rise.
  - There was support for this with 13 specifically in support and 3 not in support.

    One commenter pointed out that this should be linked to Option 49, which calls for a

  - study of wetland migration areas. One commenter believed that this should be a priority action
  - There was specific support for 'beneficial reuse of sediment'
  - One commenter wanted to recognize the built communities which have a symbiotic relationship with the surrounding wetlands.
- 30. Continue efforts to re-evaluate management strategies for existing coastal impoundments.
  - There was support for this option with 8 specifically in support and 3 not in support.

    One commenter thought that this option might want to explore in detail the value of
  - developing "new" formal management collaboration (federal and state) for the National Wildlife Refuges that incorporate the interests of the diverse communities (including farmers) that adjoins them.

- 31. Evaluate the benefits and risks of permitting privately owned coastal impoundments.
  - There was support for this with 8 specifically in support and 4 not in support.
  - One commenter said that impoundments endanger local communities
- $\ensuremath{\mathtt{32}}.$  Develop a framework for decision making regarding land protection and restoration strategies based on habitat vulnerability, migration potential and relative importance in he regional landscape, historical significance or other key factors.
  - There was mixed support for this with 7 specifically in support and 3 not in support.
  - One commenter wanted to recognize and integrate the reality of the extensive research process and management analysis that has already been done for the two federal refuges (the recently completed Comprehensive Conservation Plan).

#### INCREASE PUBLIC AWARENESS OF SEA LEVEL RISE THROUGH EDUCATION, **OUTREACH AND MARKETING**

- 33. Develop a comprehensive outreach strategy to educate public about sea level rise.
  - There was support for this with 17 specifically in support and 1 not in support.

    Two commenters thought this should be a priority action

  - . There was a suggestion to include utilities, the real estate community, farmers and insurance
  - community as targeted audiences
     One suggested that we include the "non-impacted" communities whose tax dollars are being
  - utilized to fix problems on the coast

    There was a suggestion to specifically include school children beginning no later than junior high using state science curriculum standards and to learn what other states have done for k-12 education and copy the best practices.
- 34. Provide education and outreach for impacted communities and citizens.
  - There was support for this with 8 specifically in support and 1 not in support.
  - Comment to be explicit that SLR affects some communities more than others.
    Concern that insurance be part of the discussion for communities and citizens
  - Include dangers of living behind dikes and levees in educational efforts.
- 35. Improve the ability of homebuyers to investigate a property's potential vulnerability to sea level prior to purchase. There was mixed support for this option. Approximately 16 commenters supported this option; 6 did not support it.
  - One commenter wanted to wait until there is better data about what areas sea level rise will affect, and when (phase in after data collection options 44, 47, 65 and 55)
  - One comment also addressed education efforts for living behind dikes and levees and that there may be a need for vulnerability "disclosure for people and businesses behind dikes and levees with questionable maintenance regimes
  - · Focus more on the education component, and less on the disclosure component
  - Spend more time describing the "Newark Model" Include better information about cost and availability of flood insurance in education efforts
- 36. Provide targeted outreach to water and wastewater operators and water utilities.
  - There was support for this with 5 specifically supporting and 1 not in support.

    One commenter wanted to include adding state, municipal, and county water and
  - wastewater professionals.

#### IMPROVE THE AVAILABILITY AND ROBUSTNESS OF SEA LEVEL RISE DATA SETS:

#### 37. Conduct a risk assessment for Delaware's system of dikes & levees.

There was support for this with 8 specifically supporting and 1 not in support.

- One commenter suggested that there may be a need for vulnerability "disclosure" for people and businesses behind dikes and levees with questionable maintenance regimes
- Develop and maintain a comprehensive database that contains the location and condition of all wastewater infrastructures. There was support for this with 7 specifically in support and 2 not in support
  - One commenter believed that there might be too many legal issues with this for it to be viable

#### 39. Identify data needs to plan transportation investments. There was support for this with 6 specifically in support and 1 not in support.

No specific or actionable comments received

# 40. Model potential stormwater inundation problems in highly vulnerable areas. There was support for this with 6 specifically in support and 1 not in support.

- No specific or actionable comments received
- 41. Develop a model that will predict changes to salinity in surface water that may occur under differing sea level rise scenarios. There was support for this option with
  - 4 specifically supportive and 2 not supportive.
  - No specific or actionable comments received.
- 42. **Develop a statewide groundwater model.** There was support for this option with 6 specifically in support and 2 not in support.
  - One commenter suggested we mention agriculture as an important end user of this info.

#### 43. Encourage the development of a research and policy center at a university or

college campus that would focus on applied research for sea level rise and adaptation. There was support for this with 10 specifically in favor and 2 not supportive.

- Two commenters said this should be a priority/high importance
  One commenter believed this option gets lost in a series of options about data when it
- could be a stand-alone recommendation of great importance.
- Comment that this could also be a "consortium" of research and policy resources that connect Delaware's academic institutions
- · Comment that this could be funded by a Coastal tax

## 44. Improve monitoring of current sea level conditions and improve predictions for timing of inundation. There was support for this option with 9 specifically in support and 1 not in support.

- One commenter wanted recent funding cuts (DCP note, this may reference federal budget cuts)
- . One comment that this could be funded with coastal tax

45. Increase understanding of the regional implications of loss of industrial areas in coastal Delaware. There was support for this with 6 specifically supportive and 2 not supportive.

· One commenter wanted the private sector to take more initiative

# 46. Improve understanding of impacts to adjacent properties from adaptation actions. There was support for this with 5 specifically supportive and 1 not supportive.

- One commenter thought that this is a good place to also raise the need for stormwater management requirements
- One commenter thought this was applicable also to property owners where
   "adaptive measures" might result in "water trespass" on neighboring properties.

47. Develop sea level models that incorporate storm surge impacts.

There was support for this with 15 specifically supportive and 1 not supportive.

- Many commenters (at least 6) thought this was of high importance or should be a priority
   Explain the reasons why this hasn't already been done
- Several specific comments about Inland Bays flooding and the Indian River Inlet

# 48. Foster pilot projects that demonstrate the effectiveness of best management practices

for management of agricultural lands affected by sea level rise.

There was support for this with 6 specifically supportive and 2 not supportive.

 One commenter pointed out that the Prime Hook area would be a good place to foster best management practices of agricultural land because the Farm Preservation Program is active there, salt water intrusion is increasing, and UD has been doing research at the College of Earth, Ocean and Environment on non-traditional crops better suited to such conditions.

## 49. Identify and preserve areas for potential wetland migration.

There was support for this with 13 specifically supportive and 1 not supportive.

- Link to Option 29 (develop comprehensive wetlands strategy)
- One commenter suggested prioritizing the purchase of farmland for this purpose
- Several commenters identified this as a priority item

#### 50. Encourage federal agencies to integrate sea level rise planning into their flood models.

- There was a support for this with 13 specifically supportive and 1 not in support.

   There was concern from at least one commenter that data is not yet good enough to produce reliable flood maps that incorporate sea level rise. Data from options about monitoring sea level, incorporating sea level rise into flood maps, adding tide stations should be done first.

  There was a comment to also ensure that floodplain maps are routinely updated
- (DCP comment: they are only periodically updated now with many not having been comprehensively reviewed for several decades)
- . Consider the social and economic impact of this action

## 51. Conduct research to better understand human response to sea level rise and adaptation.

There was support for this option with 7 specifically supportive and 1 not in support.

One commenter thought this was very important/should be a priority. Believes that lack of

- consideration for the human dimensions of SLR have made job of outreach and education much more difficult.
- . Could be linked to #43, development of a research center in Delaware

#### 52. Improve the accuracy of Delaware's elevation benchmark network.

There was support for this option with 7 specifically supportive and 1 not in support.

• Question about whether the 10-Year Bay Beach Management Plan produced a good model for this

- 53. Continue and expand studies regarding sediment accretion rates and susceptibility of wetlands to sea level rise. There was support for this option with 7 specifically supportive and 1 not in support.
  - No specific actionable comments received
- 54. Add additional tidal observation stations in Delaware. There was a high level of support for this with 10 supportive and 1 not supportive.
  - . No specific actionable comments received
- 55. Install inland inundation water level monitoring sites. There was support for this with 6 supportive comments and 1 not in support.
  - One commenter said that improving monitoring of inland sites is necessary to show
  - what even usually high tides can do
  - One commenter indicated that this should be prioritized
  - The more residents and property owners in the inland begin to understand that their interests are at risk just as the coast dwellers the more likely good policy and necessary resources will result.

#### PROVIDE TECHNICAL ASSISTANCE TO PARTNERS FOR ASSESSING VULNERABILITY AND CHOOSING ADAPTATION OPTIONS

56. Create a coordinated effort to provide technical assistance to local governments.

There was support for this with 12 providing supportive comments and 1 not in support.

- At least 6 commenters believed this to be a high priority item
- One commenter wanted the text to be much stronger indicating that there should be consequences for local governments who do not plan ahead (in the form of reduced assistance from the state/fed)
- Increased insurance regulation at the state was also cited as a need here
- 57. Provide land managers, fisheries managers and farmers with the information and extension support necessary to manage lands and fisheries in areas affected by sea level rise.

There was support for this with 9 providing supportive comments and 1 not in support.

- . One commenter thought this should be a priority action
- 58. Provide technical assistance for industrial and port facilities to incorporate sea level rise into investment plans and continuity of business plans. There was support for this with 10 providing supportive comments and 1 not in support.
  - There was a question as to who would be providing this technical assistance.
  - Suggestion to use the US Navy's vigorous effort and developing technical experience in adapting its world-wide port assets to SLR.
  - One commenter believed this should be prioritized
- 59. Develop best management practice manuals for adaptation in Delaware.

There was support for this with 10 providing supportive comments and 1 not in support.

Manuals could be developed in collaboration with faculty at colleges and universities

- This helps with public education and outreach in a concrete way.
- · One commenter believed this should be prioritized

- 60. Conduct a cost benefit analysis for adaptation. There was support for this option Conduct a cost benefit analysis for adaptation. Inere was support for this option with 10 commenters supportive and 3 not supportive.

  One commenter said that this can't be done until specific actions are proposed

  Add Cost/Benefit study conducted for Bay Beaches as basis

  One commenter thought this should be prioritized

  One commenter thought this would be helpful in deciding among adaptation options.
- 61. Develop a database of costs of adaptation options for use by decision-makers and the public. There was support for this with 9 comments in support and 2 not in support.

- One commenter thought that the database should include past adaptation experiences including dates, description of the work done and its total costs, and costs per unit (e.g. cubic yards of added beach, feet or meters of dike or road repaired, feet of elevation added to structures), as well as the name and contact information of the contractor
- elevation added to structures), as well as the hame and contact information of the contract who did the work as well as projections of likely future costs.
   One commenter thought that the database of costs should be connected with a technical piece on the efficacy of the actual adaptation options to be considered.
   One commenter thought this should be prioritized

# Appendix F: Acronyms

AASHTO - American Association of State Highway Transportation Officials

**BMP** - Best Management Practices

CAKE - Climate Adaptation Knowledge Exchange

CREAT - Climate Resilience Evaluation and Awareness Tool

CZA - Delaware Coastal Zone Act

**DelDOT** - Delaware Department of Transportation

**DEMA** - Delaware Department of Homeland Security, Delaware Emergency Management Agency

DNREC - Delaware Department of Natural Resources and Environmental Control

FEMA - Federal Emergency Management Agency

GIS - Geographic Information Systems

HCC - Habitat of Conservation Concern

IPCC - Intergovernmental Panel on Climate Change

ICLEI - International Council for Local Environmental Initiatives

LMSL - Local Mean Sea Level

LRTP - Long Range Transportation Plan

MHW - Mean High Water

MHHW - Mean Higher High Water

MLLW - Mean Lower Low Water

MSL - Mean Sea Level

MPO - Metropolitan Planning Organization

NOAA - National Oceanic and Atmospheric Administration, U.S. Department of Commerce

PLUS - Preliminary Land Use Service

RAS - Regulatory Advisory Service

RIP - Rehabilitation and Inspection Program

TDR - Transport of Development Rights

**TOMP** - Transportation Operations Management Plan

USACE - United States Army Corps of Engineers

# **Appendix G: Definitions**

Accretion - The accumulation of a sedimentary deposit that increases the size of a land area.

Adaptation - An action that can be taken to adjust to new or emerging conditions such as sea level rise.

**Adaptive capacity** – The ability of individuals, or agencies, to assess potential impacts and to select and implement appropriate adaptation measures to cope with a changing environment.

**Agricultural land conservation easements** – Land permanently protected through deed restrictions to maintain agricultural land and agricultural uses.

Bathtub model – A water surface model that maps flooding scenarios where the extent of inundation is estimated based on mean higher high water and land elevation. Bathtub models do not incorporate storm surges or future land conditions.

Bioswale – A naturalized landscape element that can remove silt and nutrients from stormwater run-off, improving water quality in rivers and streams. Bioswales have gently sloped sides and are frequently planted with venetation

**Beach nourishment** – A process by which sediment (sand) lost to erosion is replaced with sand from another source. Nourishment projects typically utilize large dredges to bring in sand from offshore sources, but sand mined inland can also be utilized though truck-haul.

**Brackish water** – Water that results from the mixing of a saltwater and freshwater body of water, such as in an estuary. Brackish water has a salt content of between 0.05% to 3%.

Bulkhead - A wall that is constructed parallel to a shoreline to prevent erosion.

Coastal impoundment – A man-made structure adjacent to open water or wetlands where water levels can be managed for a variety of outcomes including controlling mosquito populations, creating foraging and breeding habitat for wildlife and providing recreational opportunities.

Conservation easements – A voluntary agreement between a landowner and a government or other organization that restricts certain uses of the property for a variety of purposes (habitat creation, scenic vistas, agriculture) while the property remains in private ownership.

Datum - A point, line or surface used as a reference in measuring locations or elevations.

**Dike** – A wall generally of earthen materials designed to prevent the permanent submergence of lands below sea level or storm-surge flooding of the coastal floodplain.

**Dune** – A mound of sand parallel to a shoreline that can be built naturally by wind and water flow or can be constructed during beach nourishment projects. Dunes help protect areas inland from erosion and storm damage. They also provide important wildlife habitat.

Environmental Justice Community – Communities where residents are predominantly minority or low-income; where residents have been excluded from the environmental policy setting or decision-making process; where they are subject to a disproportionate impact from one or more environmental hazards; and where residents experience disparate implementation of environmental regulations, requirements, practices and activities.

Estuary – A partially enclosed body of brackish water that is a transition zone between river and ocean environments.

Eustatic sea level rate - The worldwide change of sea level elevation with time.

Green infrastructure – An approach to managing stormwater that utilizes natural techniques like bioswales and wetlands.

Glacier – A large and persistent body of ice that forms over a period of many years when accumulation of snow exceeds melting. Glaciers form only on land and can be found in mountain ranges of every continent except Australia.

**Geographic Information System (GIS)** – A hardware and software system that allows the visualization, analysis and interpretation of geographic data.

**Groin** – A low wall or sturdy barrier built perpendicular from a shoreline into a waterway. It is intended to reduce erosion by trapping the sand that moves parallel to the shoreline. These structures can also cause of increase erosion of adjacent shorelines.

Groundwater - Water located beneath the surface in fractures or rock formations.

Habitats of Conservation Concern (HCC) – Lands identified in the Delaware Wildlife Action Plan that are sensitive to disturbance and have a high density of rare species with ecological significance.

**Ice sheet** – A mass of glacier ice that covers land and is greater than 19,000 square miles in area. Ice sheets are also known as continental glaciers. The only ice sheets in existence today are in Antarctica and Greenland.

Inundation – The movement of coastal waters over land.

**Living shorelines** - A structure that prevents shoreline erosion and maintains coastal processes by restoring or enhancing natural shoreline habitat through the strategic placement of plants, stone, sand fill, and other organic materials.

Maladaptation - Poor or inadequate adaptation.

Marsh – A frequently or continually inundated wetland characterized by herbaceous vegetation adapted to saturated soil conditions.

Marsh migration – A process by which tidal wetlands adjust to rising sea levels by advancing inland into areas previously above the ebb and flow of the tides.

**Mean Higher Water (MHW)** – a tidal datum; the average height of high water levels observed over a 19-year period.

**Mean Higher High Water (MHHW)** – the average of the highest of the high water heights of each tidal day observed over a 19-year period known as the national tidal datum epoch.

Mean Lower Low Water (MLLW) - A tidal datum that measures the average of the lower low water height of each tidal day.

Mean Sea Level (MSL) - A tidal datum that measures the mean of hourly heights of each tidal day.

Nested Model - A model in which all of the terms of a smaller model are contained within a larger model.

Protected lands - For the purposes of this document, protected lands are lands owned by state, local and municipal government, conservation groups, and individuals including State Wildlife Areas, State Parks, historical sites, and county and municipal parks.

Public Trust Doctrine - A legal principle derived from English Common Law which holds that the waters of a state are a public resource owned by and available to all citizens and that these public property rights are not invalidated by private ownership of the underlying or adjacent land.

Resiliency - The ability to recover after an event with negative consequences.

Salt wedge - The boundary that is formed when freshwater from a river flows over more dense saltwater, forming a wedge between the freshwater and the saltwater.

Saltwater intrusion - Displacement of fresh or ground water by the advance of salt water, due to its greater

Sea level rise, local - The rise in sea level measured with respect to a specified vertical datum relative to the land, which also may be changing elevation over time. Local sea level rise is typically measured with a tide gauge.

Sea level rise, eustatic - the worldwide average rise in mean sea level.

Salt marsh - A grassland containing salt-tolerant vegetation established on sediments bordering saline water bodies where water level fluctuates with the tides.

Species composition - The number of different species present in a given geographic area.

Storm surge - An abnormal rise in sea level that accompanies a coastal storm. The height of the storm surge is the difference between the observed level of the sea surface and the level that would have occurred without influence of the storm.

Tidal wetlands - Wetlands that are exposed to the periodic rise and fall of the tides.

Tide gate - A mechanical structure that allows water to flow freely when the tide is moving in one direction, but which closes to prevent water from flowing in the opposite direction.

Tide gauge - A device that measures changes in sea level relative to a fixed land elevation. These devices measure daily tide heights and storm tide heights. Long term tide gauge records can provide local long-term sea level trends.

Vulnerability - The susceptibility of a resource to negative impacts from sea level rise.

Watershed - A drainage basin or area of land where surface water converges to a single point, usually the exit of the basin flows into a river, lake, reservoir, estuary, or ocean

Wetland - Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soils.

# Appendix H: Resources for Adaptation Planning and Implementation

The main body of this document lays out a path forward for preparing for the impacts of sea level rise to the State of Delaware, but does not put forth any specific adaptation measures for specific locations. Selection, planning and implementation of specific measures to combat sea level rise will occur through the activities of a wide variety of individuals, communities, businesses and agencies. This appendix provides those wishing to begin the process of adaptation with a list and description of resources that are currently available to help them plan, design and fund adaptation measures.

#### Planning and Technical Assistance

This section provides a list and description of programs that can provide planning and technical assistance to those wishing to plan adaptation actions or implement adaptation projects. This list is not exhaustive and is intended to be a starting point for potential adaptation projects. Where possible, contact information for a person or agency capable of providing more information or technical assistance is listed.

#### Delaware Coastal Programs

Delaware Colastal Frograms provides technical assistance, guidance, data, training and grants for a wide range of coastal issues, including planning and adapting to sea level rise. Technical assistance is available to communities, non-governmental agencies, government agencies and universities and specific training for these audiences is announced periodically. Communities and agencies seeking to begin a planning process for sea level rise and coastal vulnerability or develop specific adaptation solutions to existing flooding issues are encouraged to contact the program for assistance. Information about the Delaware Coastal Programs is available online: www.dnrec.delaware.gov/coastal.

For more information, contact:

Robert Scarborough, Ph.D Department of Natural Resources and Environmental Control Delaware Coastal Programs 5 East Reed Street, Suite 201 Dover, DE 19901 (302) 739-9283 Bob.Scarborough@state.de.us

#### Delaware Sea Grant Marine Advisory Service

The Delaware Sea Grant Marine Advisory Service is a resource provided by the University of Delaware that advocates for the wise use, conservation and development of marine resources. Information and planning assistance is available to address flooding and sea level rise as well as other coastal issues including water quality, resource management and sustainable communities. The Marine Advisory Service transfers science-based information and expertise of the University's researchers to local citizens, resource managers and business owners in a variety of ways such as workshops, publications, trainings, and consultations. Additional information is available online: http://www.deseagrant.org/outreach.

For more information contact: Jim Falk Delaware Sea Grant Marine Advisory Service University of Delaware 700 Pilottown Road Lewes, DE 19958-1298 (302) 645-4235 jfalk@udel.edu

#### Flood Mitigation Program

Delaware's Flood Mitigation Program provides flood-related assistance to individuals and communities for the purpose of reducing the state's vulnerability to flood damages. Specifically, the program helps communities comply with floodplain standards and flood insurance requirements. It also assists individuals and communities obtain funding for projects which reduce vulnerability to flooding. Information about the Flood Mitigation Program is available online: http://www.dnrec.delaware.gov/swc/drainage/pages/flooding.aspx.

For more information, contact: Michael Powell DNREC Division of Watershed Stewardship 89 Kings Highway Dover, Delaware 19901 (302) 739-9921 Michael.Powell@state.de.us

#### Office of State Planning Coordination

The Delaware Office of State Planning Coordination provides a range of information and services to local and county governments to foster responsible growth and compliance with requirements for Comprehensive Land Use Plans. Technical assistance is available to cities and towns to help incorporate sea level rise into comprehensive development plans, zoning codes and ordinances, Information about the Office of State Planning Coordination is available online: http://www.stateplanning.delaware.gov/.

For more information, contact: Constance Holland State Planning Director Office of State Planning Coordination 122 Martin Luther King Jr. Blvd. South 3rd Floor Dover, DE 19901 (302) 739-3090 Connie.Holland@state.de.us

#### Preliminary Land Use Service

The Preliminary Land Use Service (PLUS) allows for state agency review of major land use changes and comprehensive development plans. Certain development projects are required to undergo review; however, a municipal or county government can request a state review for any project regardless of size or scope. Local communities wishing to understand potential future flooding issues resulting from proposed development are encouraged to consider the PLUS process. Additional information about PLUS is available online: http://stateplanning. delaware.gov/plus.

For more information, contact: Constance Holland, AICP State Planning Director
Office of State Planning Coordination 122 Martin Luther King Jr. Blvd. South 3rd Floor Dover, DE 19901 (302) 739-3090 Connie.Holland@state.de.us

#### Private Lands Assistance Program

The DNREC Private Lands Assistance Program assists private landowners improve and protect their lands for wildlife. The program has biologists dedicated to informing landowners about available programs, providing technical assistance for developing habitat projects and securing financial assistance as incentives for participation. Landowners faced with inundation issues on their property who wish to choose a natural adaptation method are encouraged to consult with program scientists for ideas and funding. Additional information is available online: http://www.dnrec.delaware.gov/fw/dplap/Pages/default.aspx.

For more information contact: William Jones Fish & Wildlife Regional Manager Delaware Division of Fish & Wildlife 89 Kings Highway Dover, DE 19901 (302) 284-4795 William.Jones@state.de.us

Jason Davis Delaware Division of Fish and Wildlife 89 Kings Highway Dover, DE 19901 (302) 735-3600 Jason.Davis@state.de.us

#### Regulatory Advisory Service

The Regulatory Advisory Service (RAS) provides an opportunity for developers or business owners seeking to relocate or expand within the state to consult with DNREC agencies about environmental permitting and design considerations. The RAS provides a one-stop-shop for information about necessary permits and regulations but can also help individuals understand and mitigate potential future flood risk at a particular site. More information is available online: http://www.dnrec.delaware.gov/SBA/Pages/RegulatoryAdvisoryService.aspx.

For more information, contact: Gail Henderson Office of the Secretary 89 Kings Highway Dover, DE 19901 (302) 739-9909 Gail.Henderson@state.de.us

Shoreline and Waterway Management Section
DNREC's Shoreline and Waterway Management Section regulates coastal construction and
implements beach and dune management practices. Their mission is to protect and enhance the state's beaches for recreational use and to improve resilience to storm events and
erosion. The section has a variety of resources and publications to assist communities and individuals in understanding and adapting to coastal hazards including sea level rise. Additional information is available online: http://www.dnrec.delaware.gov/swc/shoreline/Pages/ Shoreline.aspx.

For more information, contact: Jennifer Luoma

DNREC Division of Watershed Stewardship 89 Kings Highway Dover, Delaware 19901 (302) 739-9921 Jennifer.Luoma@state.de.us

#### Funding and Grant Assistance

This section provides a list and description of grant and loan programs that can be utilized by agencies wishing to plan adaptation actions or implement adaptation projects. This list is not exhaustive and is intended to be a starting point for agencies seeking funding; many other funding opportunities may be available from county, federal and private source and innovative financing mechanisms. Where possible, contact information for a person or agency capable of providing more information or technical assistance is listed.

#### **Coastal Management Assistance Grants**

The DNREC Delaware Coastal Programs currently offers competitive grants of up to \$25,000 annually for coastal planning and research pertaining to coastal resiliency and sea level rise. These grants are available to state agencies, municipal and county governments, academic institutions and not-for-profit organizations. Grant funding can be used for adaptation planning (including comprehensive planning and building code updates) and adaptation project design as well as adaptation research or sea level rise monitoring. Funding cannot be used for construction. Additional information is available online: http://www.dnrec.delaware.gov/coastal/Pages/CoastalProgramRFP.aspx.

For more information, contact: Bonnie Arvay Delaware Coastal Programs
Department of Natural Resources and Environmental Control 5 E. Reed Street, Suite 201 Dover, DF 19901 (302) 739-9283 Bonnie.Arvay@state.de.us

#### Green Project Reserve

The DNREC Financial Assistance Branch offers below market rate loans for state, county and municipal agencies to assist with the planning and construction of green infrastructure, water efficiency and environmentally innovative projects. A wide range of adaptation strategies could be funded through this program. To be eligible, projects must first be placed on the Project Priority List; development of the list begins in January each year. Additional information is available online: http://www.dnrec.delaware.gov/fab/Pages/Green-Project-Reserve. aspx.

For more information, contact: Greg Pope P.E Delaware Department of Natural Resources & Environmental Control Office of the Secretary
5 E. Reed Street, Suite 200
Dover, DE 19901 Greg.Pope@State.de.us (302) 739-9941

Pre-Disaster Mitigation Program
The Federal Emergency Management Agency offers competitive grants for projects seeking to reduce risk to people and structures from hazard events, including storms and inundation. These grants are available to states, territories, tribal governments, local communities and universities. The application period is June through December each year. In most cases, applicants for funding must provide matching funds no less than 25% of the total project cost. Additional information is available online: http://www.fema.gov/pre-disaster-mitigation-grant-program.

David Carlson Delaware Emergency Management Agency 165 Brick Store Landing Road Smyrna, Delaware 19977 Phone: (302) 659-2213 David, Carlson@state.de.us

Surface Water Matching Planning Grants
The DNREC Financial Assistance Branch provides competitive grants of up to \$50,000 annually for planning and engineering design of projects that seek to improve surface water quality within the state. Adaptation projects that have a water quality component, including stormwater retrofits, wetland restoration, drainage plans and green infrastructure, would qualify for funding through this program. Funding is available to state, county and municipal agencies. A 1.1 cash match is required for the grant. More information is available online: http://www. dnrec.delaware.gov/fab/Pages/Surface-Water-Matching-Planning-Grants.aspx.

For more information, contact: Jim Sullivan Division of Watershed Stewardship Department of Natural Resources and Environmental Control 89 Kings Highway Dover, DE 19901 (302) 739-9921 James.Sullivan@state.de.us

#### Wastewater Matching Planning Grants

The DNREC Financial Assistance Branch provides competitive grants of up to \$50,000 annually to municipal and county wastewater utilities for wastewater planning projects. Projects which propose to modify facilities in order to adapt to sea level rise would qualify for funding under this program. A 1:1 cash match is required for the grant. More information is available online: http://www.dnrec.delaware.gov/fab/Pages/Wastewater-Matching-Planning-Grants.

For more information, contact:
Greg Pope P.E
Delaware Department of Natural Resources & Environmental Control
Office of the Secretary
5 E. Reed Street, Suite 200
Dover, DE 19901
(302) 739-9941
Greg.Pope®State.de.us

#### Online Tools, Guidebooks and Decision Aids

This section provides a list and description of online tools, guidebooks and decision-aids that can be used by individuals or agencies to understand the potential impacts of sea level rise and to evaluate options to adapt to sea level rise. All tools listed below are available free of charge to anyone wishing to utilize them. Where possible, contact information for a person or agency capable of providing more information or technical assistance is listed.

#### Climate Adaptation Knowledge Exchange Website

The Climate Adaptation Knowledge Exchange (CAKE) is a website that provides easy access to sea level rise adaptation case studies, adaptation reports and adaptation tools from around the country. It also provides a directory of adaptation practitioners and experts and a discussion form. Its "virtual library" provides options for targeted searches on scientific research and planning strategies. The website is available here: www.cakex.org.

For more information, contact: EcoAdapt P.O. 80x 11195 Bainbridge Island, WA 98110 Phone: 206 201 3834 info@cakex.org

#### CREAT Tool

The Climate Resilience Evaluation & Awareness Tool (CREAT) is a software tool developed by the U.S. Environmental Protection Agency to assist drinking water and wastewater utility owners and operators understand potential climate change threats and related risks at their acilities. The tool helps water utility operators plan for sea level rise by providing risk reduction and cost reports for evaluation of potential adaptation options. CREAT also provides users with access to the most recent national assessment of climate change impacts for use in considering how these changes will impact utility operations and missions. The software can be downloaded free of charge at http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm.

For more information: U.S. Environmental Protection Agency Region 3 1650 Arch Street Philadelphia, PA 19103-2029 (800) 438-2474 CREAThelp@epa.gov

Delaware Homeowner's Handbook to Prepare for Natural Hazards
The "Delaware Homeowners Handbook to Prepare for Natural Hazards" is a guidebook for Delaware homeowners interested in preparing themselves and their homes for coastal storms, flooding, tornadoes, sea level rise and climate change. It provides practical information about steps that can be taken to prevent damage to homes in the event of storms and provides information about flood insurance. In addition, the guidebook contains emergency contact numbers and shelter information. The guidebook can be downloaded online: http://www.deseagrant.org/sites/deseagrant.org/files/product-docs/DE\_Homeowner\_Handbookir.

For more information, contact: Dr. Wendy Carey Delaware Sea Grant Program 700 Pilottown Road Lewes, DE 19958 (302) 645-4258 wcarey@udel.edu

#### Delaware Sea Level Rise Viewer

The Delaware Sea Level Rise Viewer is a web-based mapping tool developed by the DNREC Delaware Coastal Programs that allows users to visualize the potential impact of sea level rise within Delaware under three scenarios—0.5 meter, 1.0 meter and 1.5 meters in 2100. The map is based upon existing elevation data and does not account for future rates of erosion, subsidence, or construction. Water levels are shown as they would appear during an average high tide (mean higher high water). The viewer can be accessed online: http://de.gov/slrmap.

For more information, contact: Susan Love Delaware Coastal Programs 5 East Reed Street, Suite 201 Dover, DE 19901 (302) 739-9283 Susan.Love@state.de.us

#### **Digital Coast Website**

The Digital Coast Website provides data, tools and training modules for decision-makers to address coastal issues, including sea level rise and climate change. This website hosts the U.S. Sea Level Rise and Coastal Flooding Impacts Viewer and provides a portal for users to download mapping data. It also provides Coastal County Snapshots for flooding in all of Delaware's counties, providing a quick way for decision makers to understand land use, population and demographic changes inundation. It also provides several downloadable modeling tools. The website is available here: http://csc.noaa.gov/digitalcoast/.

#### Getting to Resilience Website and Questionnaire

The Getting to Resilience Questionnaire is a non-regulatory tool created by the New Jersey Department of Environmental Protection's Coastal Management Program to assist local decision makers identify planning, mitigation and adaptation opportunities for coastal storm and sea level rise. The questionnaire is intended to stimulate dialogue among local leaders as they answer the questions it poses about storm and sea level rise preparedness and identify actions that can be taken to improve resiliency to storms and sea level rise. Although developed specifically for communities in New Jersey, it can easily be transferred and utilized in Delaware communities. The questionnaire can be filled out online at www.prepareyourcommunitynj.org or downloaded at www.state.nj.us/dep/cmp/docs/gtr-resilience.pdf.

For more information, contact: Lisa Auermuller, Watershed Coordinator Jacques Cousteau National Estuarine Research Reserve (609) 812-0649 x204 auermull@marine.rutgers.edu

#### Storm Smart Coasts Delaware Website

The Storm Smart Coasts website is a web resource designed to provide local and state officials with resources for addressing the challenges of storms, flooding, sea level rise and climate change. It has information specific to Delaware on these topics specifically tailored to planning board members, council members, town managers, building officials and public works departments. It can be used to prepare for a storm, communicate with emergency contacts during a storm, provide for safe and smart recovery after a storm and seek funding. Website users can also find and contact peers through the site, share files and create or join discussion groups. The website is available here: http://de.stormsmart.org/.

U.S. Sea Level Rise and Coastal Flooding Impacts Viewer
The U.S. Sea Level Rise and Coastal Flooding Impacts Viewer is a web-based mapping tool
developed by the National Oceanic and Atmospheric Administration that allows users to visualize the potential impacts of sea level rise and coastal flooding in the U.S. at 1-foot increments. It also provides visualizations of sea level rise at local landmarks, communicates the
uncertainty of mapped sea levels and models potential marsh migration due to sea level rise. Users can also overlay social and economic data and examine how tidal flooding will become more frequent with sea level rise. The viewer can be accessed online: http://www.csc.noaa. gov/digitalcoast/tools/strviewer.

For more information, contact: NOAA Coastal Services Center 2234 South Hobson Avenue Charleston, SC 29405-2413 (843) 740-1200 www.csc.noaa.gov

# Appendix I: Funding Options Considered

The information presented in this appendix is meant to inform implementation of Recommendation 7.1, which calls for the convening of an expert panel to provide an assessment and analysis of funding options for adaptation measures. It presents both ideas that were discussed by the advisory committee but dropped from consideration and ideas that were submitted during the public engagement sessions held in February 2013. The Sea Level Rise Advisory Committee did not endorse any of these ideas; they are simply presented here as information that could be useful for subsequent activities.

#### Specific Comments about Funding from Public Engagement Sessions

In its comment form for the adaptation public engagement sessions, the Sea Level Rise Advisory Committee asked the question: "Adapting to sea level rise can be costly for individuals, businesses and governments alike. Do you have ideas about how adaptation projects should be paid for?" At least 6 commenters specifically requested or encouraged the advisory committee to include funding provisions in the final plan and emphasized the importance of this issue. Many specific funding ideas were also submitted.

Public comments in response to this question generally fell in to one of four categories: (1) specific ideas for new or revised revenue streams, (2) general principles for spending funding (3) incentive and disincentives, or (4) new approaches that reduce need for revenue.

#### Specific Ideas for new or revised revenue streams

- · Create a carbon tax
- Create a National Flood Tax
- Increase the rate for Delaware's Public Accommodations Tax
- Include short-term rentals in Delaware's Public Accommodations Tax
- Allow for funds from the Public Accommodations Tax to be spent in New Castle County (and northern Kent)
  - Specific comments from a resident of Woodland Beach were received. expressing frustration that she couldn't get help for erosion issues from the state.
- Reassess properties to increase funds to local governments from property taxes
- Implement a Coastal Security and Preservation Tax
- Increase the Real Estate Transfer Tax on homes near the coast
- include a check-box on Delaware state taxes for contributions for adaptation

#### Fees

- Create new laws giving the Department of Natural Resources the authority to regulate development in the floodplain; set permit fees high enough to provide revenue for adaptation.
- Create a stormwater utility
- Add a surcharge on the Route 1 toll to fund transportation adaptation projects

#### Incentives and Disincentives

- Include sea level rise in the funding and/or selection criteria for state funding programs
  - Water Pollution Control Revolving Fund
     Drinking Water State Revolving Fund
- Allow funding/assistance for local governments/communities only if they have already implemented "best practices"
- Provide funding for sea level rise planning

#### General Principles for spending funds

- Require a local/community cost-share for adaptation projects
  - This particular idea came up numerous times, particularly with regard to drainage problems and beach replenishment
- Don't pay for short term fixes invest in long term solutions
- Encourage planning for sea level rise through carrot and stick approaches
  - Incentivize good practices with grant funding or special programs
  - Deny funding to parties who are not participating

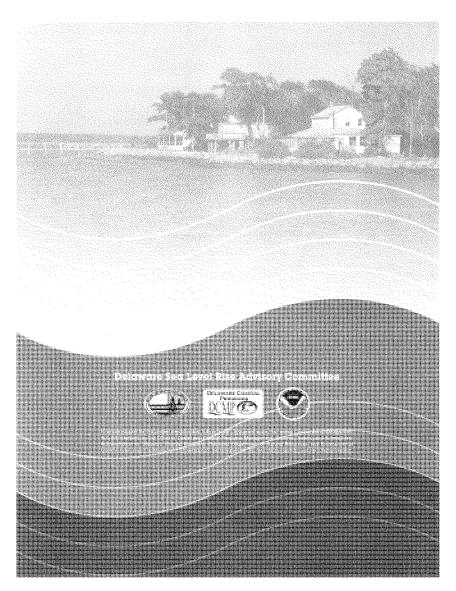
#### **New Approaches**

- Utilize innovative financial strategies
- This could include reverse mortgages for long-term buyouts
   Not specifically mentioned in comments, but could be considered under this category
- Property Assessed Clean Energy (PACE) example: homeowner upgrades paid for through loans made to homeowners through municipal bonds that are repaid via annual assessment on their property tax bill
- Special Financing Districts: Yearly taxes or fees established voluntarily by property owners within a specific geographic area for a community purpose. In Delaware, Tax Ditches and Tax Lagoons are an example

## Initial List of Funding Ideas Considered by the Sea Level Rise Advisory Committee

The following list of ideas was generated for the consideration of the Sea Level Rise Advisory Committee as a result of focus group sessions held in October, 2012. These ideas were deleted from consideration prior to the public engagement sessions in February 2013 as the advisory committee thought it was premature to discuss any funding options until the overall funding need in the state was better understood. The following ideas, coupled with the ideas above that resulted from the public meetings, will be taken into consideration for the implementation of Recommendation 7.1.

- · Modify the Hotel Accommodations Tax to increase funds
- Revise Strategies for State Spending to allow State Revolving Fund and other public funding to be allocated for projects in Level 4 areas
- Create a Revolving Loan Fund for adaptation responses
- Consider use of Regional Greenhouse Gas Initiative funds for adaptation actions in industrial areas
- Evaluate the federal Farm Bill or farmland conservation programs to identify financial compensation to encourage wetland migration on farmlands adjacent to wet areas
- Possible, broad funding sources: Total Maximum Daily Load funds, Cancer Settlement Funds, Hazardous Substance Cleanup Act funding, Federal Highway Administration Moving Ahead for Progress-21 Funding, and the new federal Energy Bill
- Increase funding availability for the Port of Wilmington



### Post-Hearing Questions for the Record Submitted to the Honorable David F. Heyman and Caitlin A. Durkovich From Senator Tom Coburn

## "Extreme Weather Events: The Costs of Not Being Prepared" February 12, 2014

Question#:	
Topic:	Disaster Assistance Costs
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Coburn
Committee:	HOMELAND SECURITY (SENATE)

**Question:** The federal government is bearing a growing share of the financial burden for natural disasters and developers and local authorities know that the federal government will pay a significant share of the costs of disasters. Since 2005, it is estimated that the federal government has borne almost 70% of the cost of major hurricanes; in the fifteen years before that, the federal government bore 26% of those costs. This increase feeds local and private disincentives to avoid development in risky areas.

What is the most effective way to break the cycle of risky development and federal disaster assistance?

Response: The U.S. Department of Homeland Security (DHS) shares the Committee's concern over increasing costs borne by the federal government from natural disasters in recent years, and the need to discourage development in riskier areas. The 2010 National Security Strategy emphasizes the importance of developing incentives for government and the private sector to design structures and systems that can withstand disruptions and mitigate associated consequences. In addition, one of the critical recommendations stemming from the Hurricane Sandy Task Force was the need to establish a minimum flood risk reduction standard for any projects in the Sandy-affected region using federal funds. The Hurricane Sandy Rebuilding Strategy also recommends resilience investment guidelines designed to help ensure infrastructure will be resilient to regional hazards.

In response to this direction, the federal government is taking a number of actions; one of which is encouraging adoption of new standards, with the goal of significantly enhancing resilience by targeting high performance building attributes that enable structures to better withstand, respond to, and rapidly recover from disaster.

A recent example of such efforts is Resilience STAR<sup>TM</sup>, a new DHS pilot program designed to provide a voluntary designation for homes built to be resilient in the face of disasters. The Resilience STAR<sup>TM</sup> pilot is a partnership between DHS and the Insurance

Question#:	1
Topic:	Disaster Assistance Costs
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Coburn
Committee:	HOMELAND SECURITY (SENATE)

Institute for Business and Home Safety (IBHS). 141 applications were received for the initial pilot in the Gulf Coast, which began in November 2013.

It is difficult to identify the single most effective way to break the cycle of risky development. Many factors enter into decisions about development in risky areas and investment in manmade and natural protection efforts. Multiple economic, social, political, existing legislative, and environmental factors influence decisions which are made at the state and local level. At the direction of the President in Executive Order 13653 on Preparing the U.S. for the Impacts of Climate Change, Federal agencies including DHS are working to reform policies and Federal funding programs that may, perhaps unintentionally, increase the vulnerability of built and natural systems, economic sectors, natural resources, and communities, while seeking to remove or reform barriers that discourage investments or other actions to increase the Nation's resilience.

Question#:	2
Topic:	Critical Infrastructure
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Coburn
Committee:	HOMELAND SECURITY (SENATE)

**Question:** In Mr. Gaffigan's testimony, he notes that the National Oceanic and Atmospheric Administration estimated that "within 15 years, segments of Louisiana State Highway 1—the only road access to Port Fourchon, which services virtually all deep sea oil operations in the Gulf of Mexico, or about 18 percent of the nation's oil supply—will be inundated by tides an average of 30 times annually ...."

How does DHS account for the possibility of future extreme weather events in identifying privately owned or operated critical infrastructure?

Response: A determination of the criticality of infrastructure—whether publicly or privately owned—is based on the extent to which damage or destruction of an asset or system will adversely affect national security and public safety, as well as the safety and security of people and property in the surrounding area. Infrastructure identified as nationally critical may differ from the assets and systems that are deemed critical at a regional or local level. Once infrastructure is identified as critical (at a national or lower jurisdictional level), the first step is to identify and assess the risks to those assets and systems.

DHS applies an all-hazards approach to risk management, which considers all threats and hazards—both natural and manmade—to inform the development and implementation of appropriate measures to manage and reduce those risks. Consistent with the all-hazards approach, critical infrastructure owners and operators consider the risks associated with extreme weather events, along with other relevant threats and hazards, when deciding how best to strengthen the security and resilience of infrastructure and when siting and constructing new infrastructure facilities.

**Question:** Does the Department maintain a list of critical infrastructure and key resources that are likely to be impacted by extreme weather events, like Port Fourchon?

Response: Yes, in accordance with the Implementing Recommendations of the 9/11 Commission Act [Public Law 110-53 (Aug. 3, 2007)], the Department maintains a single classified prioritized list of systems and assets that "would, if destroyed or disrupted, cause national or regional catastrophic effects." The National Protection and Programs Directorate's Office of Cyber and Infrastructure Analysis (OCIA) execute the requirement through the National Critical Infrastructure Prioritization Program (NCIPP), which identifies qualifying domestic (Level 1 and Level 2) infrastructure. The Department uses the list to help prioritize infrastructure protection and preparedness

Question#:	2
Topic:	Critical Infrastructure
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Coburn
Committee:	HOMELAND SECURITY (SENATE)

activities, and serves as an input in FEMA's determination of risk for its Homeland Security Grant Program. In addition, during incidents OCIA develops dynamic Infrastructure of Concern lists, which prioritize critical infrastructure based on the unique threat or hazard to response and recovery efforts by the Department or other Federal, State, local and private sector partners. These lists are updated as the situation warrants. The Department also provides consequence analysis of impacts to critical infrastructure to inform decisions during disasters, but also to support preparedness activities in advance of incidents. For example, in 2011, the Department published a joint product by the National Infrastructure Simulation and Analysis Center (NISAC), which is managed by OCIA, and the National Incident Management Systems and Advanced Technologies (NIMSAT) Institute at the University of Louisiana at Lafayette examining the potential impacts of disruptions to Louisiana State Highway 1. Scenarios in the study included an extreme weather event washing out the highway, and the other being the gradual submersion of the road due to climate change and regional subsidence.

Question#:	3
Topic:	Calculating and Prioritizing Risk
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Coburn
Committee:	HOMELAND SECURITY (SENATE)

**Question:** According to Climate Change Adaptation Roadmap, "DHS uses a risk-informed approach to examine the threats, vulnerabilities, and potential consequences of climate change to the DHS mission space."

How does the Department calculate the risk of climate change? Please describe the specific approach the Department uses in the calculation.

How does DHS prioritize climate change issues against other homeland security threats?

**Response:** DHS's initial assessment produced in 2010 entailed a 3-step process: (1) Identifying the potential climate change impact, (2) Linking the impact to potential DHS vulnerabilities, and (3) Determining the likely consequences. This process established the baseline for DHS.

Since the initial assessment, DHS has refined its approach for how it incorporates climate change into its overall risk assessments. As part of the Quadrennial Homeland Security Review (QHSR) 2014 preparatory activities, DHS executed a comprehensive strategic environment assessment integrating current risk information, including threats, hazards, vulnerabilities, and consequences, with trends, longer term uncertainties, and system relationships to qualitatively explore interdependencies and how the risk posed by different threats and hazards might evolve over time. Climate change is considered a key trend and uncertainty among many dynamic aspects of the strategic environment that the Department must prepare for and monitor. This analysis suggests that climate change is among the top drivers of risk in homeland security. Trends associated with climate change may indirectly act as "threat multipliers", including aggravating stressors like poverty and social tensions abroad that can enable terrorist activity, changing patterns of human, animal, and plant diseases which could put both the workforce and the general public at ports of entry at higher risk of illness, and intensifying weather events and their associated consequences. When GAO added climate change to the High Risk List in 2013, it was consistent with the Department's view that climate change influences the likelihood and potential consequences of specific threats and hazards that pose risk to the nation and execution of our missions.

DHS has a chartered group, the Climate Change Adaptation Executive Steering Committee, charged with leading the "One DHS" effort on climate adaptation. The group looks to ensure that DHS's plans, strategies, businesses practices, and programs account for emerging risks that climate change presents to the execution of its mission.

Question#:	3
Topie:	Calculating and Prioritizing Risk
Hearing:	Extreme Weather Events: The Costs of Not Being Prepared
Primary:	The Honorable Tom A. Cobum
Committee:	HOMELAND SECURITY (SENATE)

The Executive Committee also oversaw development of the DHS Climate Action Plan (CAP). The CAP is aligned to and helps implement the vision of the President's Climate Action Plan.

To provide a sense of the mission risks, here are some examples:

Mission 1 – Preventing Terrorism: Climate change could act as a "threat multiplier" making social conditions more favorable to support terrorist activity.

Mission 2 – Securing and Managing our Borders and Mission 3 – Enforcing and Administering our Immigration Laws: Severe droughts and tropical storms could increase population movements, both legal and illegal, across U.S. borders.

Mission 4 – Safeguarding and Securing Cyberspace: Higher temperatures and more intense storms could disrupt cyber and communications networks.

Mission 5 – Ensuring Resilience to Disasters: Extreme weather events could stress the nation's capacity to respond, in particular, more intense weather-related catastrophes may challenge requirements for emergency services for the populations of coastal communities.



United States Government Accountability Office Washington, DC 20548

April 1, 2014

The Honorable Thomas R. Carper Chairman Committee on Homeland Security and Governmental Affairs United States Senate

The Honorable Tom Coburn Ranking Member Committee on Homeland Security and Governmental Affairs United States Senate

Attention: Laura Kilbride

Dear Mr. Chairman and Mr. Ranking Member:

Enclosed is our response to the questions you submitted for the record regarding our February 12, 2014, testimony entitled Extreme Weather Events: Limiting Federal Fiscal Exposure and Increasing the Nation's Resilience (GAO-14-364T). If you should have any questions, please contact me on 202-512-3841 or gaffiganm@gao.gov or my Assistant Director, Mike Hix, on 202-512-6497 or hixm@gao.gov.

Sincerely yours,

Mark Gaffigan
Managing Director, Natural Resources and Environment

Enclosure

## RESPONSE TO QUESTIONS FOR THE RECORD FOR MARK GAFFIGAN U.S. GOVERNMENT ACCOUNTABILITY OFFICE SUBMITTED FROM RANKING MEMBER TOM COBURN

# HEARING ON EXTREME WEATHER EVENTS: THE COSTS OF NOT BEING PREPARED SENATE COMMITTEE ON HOMELAND SECURITY AND GOVERNMENTAL AFFAIRS

February 12, 2014

Black Text = Introductory Text and Questions for the Record

Text in Boxes = GAO's Response

Blue Text = Hyperlinks to Cited Reports

#### **Coastal Protection Projects**

Engineered coastal protection may help reduce losses to smaller storms, but they may also result in more public works and public spending in at-risk areas so that more investments and critical infrastructure and personnel are vulnerable to large events, thereby decreasing national resilience from larger events

1. Do these projects result in development patterns that increase the risk from larger events?

GAO has not reported directly on whether coastal protection projects result in development patterns that increase the risk from extreme weather events. However, two reports provide relevant information:

First, GAO's February 2013 high risk designation entitled *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* notes that "whatever is not covered by insurance or built to be resilient to such events increases the federal government's implicit fiscal exposure through federal disaster relief programs. Fiscal constraints will make it more difficult for the federal government to respond effectively in the future, and such expenses could affect resources available for other key government programs."

Second, GAO's October 2013 report on fiscal exposures states that the government's response to an event or series of events can strengthen expectations that the government will respond in the same way to similar events in the future. The magnitude of the exposure in a given area may also change: for example, increased population density in coastal areas may increase the magnitude of exposures from natural disasters (GAO-14-28).

2. What is the most effective way to break the cycle of risky development and federal disaster assistance?

Although there is no simple or single way to break the cycle of risky development and federal disaster assistance, the recovery efforts from Hurricane Sandy and other recent disasters show the importance of encouraging mitigation measures--efforts to help minimize damage from future disasters--during disaster recovery to protect billions in federal investments. According to FEMA, mitigation

- (1) creates safer communities by reducing loss of life and property damage. For example, the rigorous building standards adopted by 20,000 communities across the country are saving the nation more than \$1.1 billion a year in prevented flood damages.
- (2) allows individuals to minimize post-flood disaster disruptions and recover more rapidly. For example, homes built to NFIP standards incur less damage from floods. When floods cause damage, flood insurance protects the homeowner's investment, as it did for the more than 200,000 Gulf Coast residents who received more than \$23 billion in payments following the 2005 hurricanes.
- (3) lessens the financial impact on individuals, communities, and society as a whole. For example, a recent study by the Multi-hazard Mitigation Council shows that each dollar spent on mitigation saves society an average of four dollars.

In addition, in response to the Sandy Recovery Improvement Act, FEMA issued a report to Congress in September 2013 providing recommendations for the development of a national strategy for reducing costs, loss of life, and injuries associated with extreme disaster events in vulnerable areas of the United States. GAO currently has work under way assessing how federal agencies administer and coordinate multiple programs to fund recovery and mitigation to encourage mitigation projects during recovery.

#### **National Insurance Programs**

The Senate recently passed S.1926, a bill both Chairman Carper and I opposed that would impose a five year delay on potential National Flood Insurance Program (NFIP) rate increases.

1. What are the long term implications of delaying NFIP rate increases?

We have previously reported that the extent that NFIP charges less than full-risk rates on properties adds to the risk that the program will need to borrow from the Department of the Treasury (Treasury) to pay claims (GAO-11-297). Subsidized policies have been a financial burden on NFIP because of their relatively high losses and premium rates that are not actuarially based. As a result, the annual amount that NFIP collects in both full-risk and subsidized premiums is generally not enough to cover its operating costs, claim payments, and principal and interest payments for the debt owed to Treasury, especially in years of catastrophic flooding. This arrangement results in much of the financial risk of flooding being transferred to the federal government and ultimately the taxpayer (GAO-14-179).

The implementation of the Biggert-Waters Flood Insurance Reform Act of 2012 (Biggert-Waters Act) was expected to decrease the number of subsidized NFIP policies. As the number of subsidized NFIP policies would decrease, NFIP's premium shortfall would decrease, helping its financial condition. We have reported that delaying or repealing NFIP rate increases in the Biggert-Waters Act may address affordability concerns but would likely continue to increase NFIP's long-term burden on taxpayers (GAO-14-127).

Delaying Biggert-Waters Act rate increases could impede private sector insurers from entering the flood insurance market, given the extent to which NFIP rates are lower than the private sector could profitably charge. We previously reported that demonstrating the political will to charge full-risk rates within NFIP could signal to private insurers a greater likelihood of being allowed the freedom to charge adequate rates in a private flood insurance market, thus encouraging their potential participation. Delaying NFIP rate increases could make private insurers' participation unlikely in the foreseeable future, as it may reinforce their skepticism about the feasibility of charging adequate rates and participating in a private flood insurance market (GAO-14-127).

2. Aside from a possible delay to NFIP rate increases, what other hurdles do NFIP or the National Crop Insurance Program face in accounting for possible increases in severity or frequency of extreme weather events?

We are conducting ongoing work that will address challenges facing NFIP and the Federal Crop Insurance Corporation (FCIC) in identifying and managing their exposure to possible increases in the severity or frequency of extreme weather events, and expect to issue a report in Fall 2014. This work will follow up on a report we issued in 2007, GAO-07-285.

In our 2007 report, we assessed the financial risks of climate change to FCIC and NFIP and found that the programs' exposure to weather-related losses had grown substantially over time. We recommended that the Secretaries of Agriculture and Homeland Security analyze the potential long-term fiscal implications of climate change for the FCIC and NFIP, respectively, and report their findings to Congress. The agencies agreed with our recommendation and subsequently issued reports. <sup>1</sup>

Our ongoing work will assess how FCIC and NFIP have implemented our recommendation and will identify challenges for the programs in managing their fiscal exposure to risks associated with climate change, among other issues. Specifically, we will review:

- What is known about how climate change has or may affect insured and uninsured property losses, and how have private and federal exposures to such losses changed since 2007?
- What steps, if any, have public insurance programs taken since 2007 to prepare for potential climate change impacts, and what associated challenges, if any, do they face?
- What steps, if any, are selected private insurers taking to prepare for potential climate change impacts and what associated challenges, if any, do they face?

<sup>&</sup>lt;sup>1</sup>See RTI International, *Climate Change Impacts on Crop Insurance*, a report prepared at the request of the U.S. Department of Agriculture Risk Management Agency, Dec. 2009; and AECOM, in association with Michael Baker Jr. Inc. and Deloitte Consulting, LLP, *The Impact of Climate Change and Populatian Growth on the National Flood Insurance Program through 2100*, a report prepared at the request of the Federal Insurance and Mitigation Administration, Federal Emergency Management Agency, June 2013.

#### Post-Hearing Questions for the Record Submitted to Lindene Patton From Senator Tom Coburn

## "Extreme Weather Events: The Costs of Not Being Prepared" February 12, 2014

#### Role of the Insurance Industry & Federal Government

1. What can be done by the insurance industry and the federal government to reduce uninsured losses from extreme weather events?

The first priority would be to reduce overall losses by improving resilience to extreme weather events.

Improvements in resilience to infrastructure – particularly power delivery systems, water delivery and treatment systems and primary transportation routes should be a priority.

I identified a few suggestions in my testimony to get at overaII loss reduction, including (a) using the language of the Extreme Weather Title of the Water Resources Development Act as an example of what could be applied to improve the resilience requirements framing the hundreds of billions of dollars the federal government invests annually in water, port, highway, transit and aviation infrastructure; and (b) expanding the DHS Resilience Star Pilot to Commercial and entire Community applications.

Encouraging the use of private insurance would also have value since insurance per se enhances economic resilience to disaster as discussed in my underlying testimony with specific reference to the Bank of International Settlements study. At the same time, however, we know that there are cognitive biases and people tend to underestimate low frequency, high impact risks. So I believe that there is a role in public education programs as well to enhance risk awareness

Insurers can and do provide information and advice regarding actions and investments that could be taken to improve resilience of assets and operations to extreme weather events. To the extent that the assets or activities are uninsured and insurers might use their corporate social responsibility programs to enhance resilience in communities, as Zurich does today.

Improving societal resilience will require a coordinated education effort utilizing insurance expertise and skills and federal support and resources:

- Public Education what does insurance cover, what are the limits of post disaster relief provided by the government. Education on risk awareness and how to improve risk management to increase economic sustainability could be a core skill insurance brings to the table
- Educate Policymakers state and locals need to understand the value of improved resilience (reduced business interruption, timely rebuilding of damaged homes and businesses) and what are the limits of insurance and post disaster relief

- Insurers and the federal government must devise incentives for greater investment in resilience
- Require new and rebuilt infrastructure to be built to more resilient standards
- Develop compelling data on the enormous cost savings to individuals, communities and the federal government by making investments in resilience – a potential GAO Report quantifying return on resilience investments – which have a direct future disaster risk reduction value.

#### Federal Disaster Recovery Funding

2. Do you believe ex-post disaster recovery creates a moral hazard, dis-incentivizing individuals and state and local governments from taking out private insurance because they assume the federal government will cover their losses in the event of a disaster?

This post-Sandy disaster studies done and reported to the Federal Disaster Recovery Coordination Group, as well as work by Jaffe and Cummins in my written testimony, suggest that citizens may be less inclined to insure assets because of a (mis)perception that disaster recovery funds will replace their personal assets. The ongoing pattern over the last several decades of increasingly generous disaster recovery funding contributes to this (mis)perception according to the researchers.

To address this challenge, actions might be taken by the federal government (DHS in particular through NFIP or Resilience Star or other programs) to provide communities and individuals a factual assessment of the benefits they can expect from the federal government when disaster strikes \PRIOR to a disaster – and to contrast these benefits with those available through insurance, including differences in the time frame in which the respective benefits become available..

Other technical risk management finance issues will also need to be addressed in the area of flood in specific as is suggested by the article published after my testimony and appended here which looks at flood modeling and disaster risk financing. The article is entitled "Increasing stress on disaster-risk finance due to large floods" by Brenden Jongman etal, published 2 March 2014 Nature Climate Change DOI: 10.1038/NCLIMATE2124

3. What trends are occurring in this area?

The research cited in my testimony indicates that the federal share of disaster response payments has increased from about 30% to about 68% over the last 3 or more decades. More research is required in this area to discern conclusive drivers for this trend. Specifically the work of Jaffe notes with respect to moral hazard and incentives to reduce risk that the major complication in assessing the welfare value of insurance is the

interaction between four factors – increasing severity of the catastrophes, the rising trend of governmental aid, the substitution of government insurance for private insurance and the incentive of homeowners and the government itself not to mitigate<sup>1</sup>. Overall, the trends show that disaster response costs are on the rise at a rate much greater than other economic adjustments like inflation. As noted above, to reduce this trend, action must be taken to improve resilience of assets and operations to extreme weather events as soon as possible.

#### National Flood Insurance Program

4. To what extent do you see programs like the National Flood Insurance Program and the National Crop Insurance Program reducing natural disincentives to risky behavior, like building in flood-prone areas?

The National Flood Insurance Program (NFIP) was not designed to discourage building in flood plains.

Much has been written about the challenges facing NFIP and its current debt. Work in Congress resulted in passage of some reforms (Biggert Waters Act) which would have among other things required that the NFIP transition to a full risk based pricing methods. Recent Congressional actions suspended those reforms. Researchers such as those at the Wharton School recommend full risk based pricing with a separately administered means-based voucher system to address both fairness and affordability – as well as to improve risk based pricing information for the public and to introduce transparency and fiscal discipline into the process. Other technical modeling experts (RMS and others) have suggested changes to those modeling and underwriting techniques applied by FEMA to inject developments in physical and actuarial science used in private industry natural catastrophe modeling and underwriting.

Another item that might be addressed to reduce or eliminate certain risky behavior could be to take action prevent further damage to naturally occurring flood resilience systems. As is well documented, inadequate flood plain maps are being relied upon by the public and policymakers and are leading to construction and reconstruction in riparian areas that never should be built upon. While some updates to flood mapping are occurring, others are not. The continued destruction of riparian lands and wetlands are contributing to significantly greater downstream flooding.

The National Crop Insurance Program has multiple policy goals but none are designed to improve resilience per se. For example, the scope of the program and recent Board meeting activities are found at <a href="http://www.rma.usda.gov/FCIC/">http://www.rma.usda.gov/FCIC/</a>; and a program called RAMP under the associated administration is focused on pesticide management but not necessarily asset resilience or asset loss avoidance. (See <a href="http://www.nifa.usda.gov/fo/riskavoidanceandmitigation.cfm">http://www.nifa.usda.gov/fo/riskavoidanceandmitigation.cfm</a>)

<sup>&</sup>lt;sup>1</sup> Jaffe, Geneva Association papers., 2013 (1-26) Page 2 The Welfare Economics of Catastrophic Losses and Insurance..

The recently enacted Farm Bill calls for a significant expansion of the Crop Insurance Program and the development of the regulations and policies for its implementation will be critical to the reduction of flooding. The conservation compliance provisions should be central to protecting sensitive lands (riparian and wetlands systems) that play a critical role in reducing downstream flooding perhaps unintentionally incentivized by national insurance.

- 5. What advantages does private insurance provide in this context?
  - Sending proper price signals through higher risk based premiums reducing development in areas prone to flooding and to development of areas which cause or exacerbate flooding in other areas.
  - Reduced costs to taxpayers post disaster emergency appropriations can be reduced
  - Provides greater incentives for individuals and society to make investments in resilience; manage risk in an economically sustainable manner and provide guidance in ensuring consistent standards are followed
  - Education and advice on risk-reduction opportunities and what adequate control of the remaining risk could or would be

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